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A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Plantation Jobs for Local Young Men:

A matter of fact discussion of the opportunities for local young men to find employment on sugar plantations brings out statistics on the number of openings likely to be available, and makes comparison with an estimate of the number of those attaining working age. This indicates the need of some outside source of labor for several years to come. A practical means of introducing young men to the work of the plantations has been developed through the "citizen's training gang." We are told that the response of the young men to the opportunities thus offered is gratifying. The young men of Hawaii are evidently to take up the work that Hawaii has to offer them, and one way of satisfactorily introducing them to it is outlined in this article.

Improvement of Field Experiments:

The large difference in the average yields of two similarly treated series of plots, closely adjacent, shows the necessity for greater care in the selection of a representative area for field experiments. A study and consideration of the factors that were concerned with the greater yield variations of experimental plots during the last three crops indicates opportunities that are still open for the improvement of our field experiments.

New Irrigation Methods:

Information on new irrigation methods is given in the form of a discussion that took place at the last annual meeting of the Association of Hawaiian Sugar Technologists, together with the introductory paper on which the comment was based.

Sunlight Hours in Hawaii:

The effect of the time of year, the angle of the slope of the cane field, and the direction of the slope of the field, on the intensity of sunlight are dealt with and are explained by diagram.

Beri-beri:

Beri-beri is a disease which continues to take its toll from the energy and life of our population through ignorance of simple nutritional precautions which are pointed out in a bulletin issued by the Queen's Hospital.

Composition of a Cane Crop:

This paper points out that a crop generally consists of cane of different age groups, which are materially different from each other both in quality and total quantity. It also shows that the average juice quality of a crop is a composite between the stalks of different ages, and within the same stalk this quality is also a composite between the dead-leaf and green-leaf parts. It is suggested that only through these conceptions of the elements of a crop can we hope to gain a clearer understanding of the interrelated problems of cane tonnage and quality.

Soil Moisture and Cane Elongation:

The magnification of the rate of growth of a cane plant by means of a balanced mirror has permitted precise observations upon the effect of soil moisture upon cane elongation. Results of extended studies with this device indicate that complete growth cessation sets in when the soil moisture is reduced to the permanent wilting percentage, as has been previously suggested. Moreover, the period of retarded growth preceding complete cessation seems to be associated with the difference in the demands for transpiration during the day and night. A similar device for use in the field is under construction.

Plantation Jobs for Local Young Men*

By E. W. Greene
Manager, Oahu Sugar Company, Ltd.

The members of your Association and the members of the Hawaiian Sugar Planters' Association are, and for many years have been, deeply interested in employing in the sugar industry as many as possible of the young men who are growing up in Hawaii.

Leaders of the industry at various times have clearly set forth their guiding policy in matters pertaining to employment, of which the following quotations are examples:

Quotation from the address of A. W. T. Bottomley in 1930 as retiring president of the Hawaiian Sugar Planters' Association:

At the beginning I desire to say with all the emphasis that can be carried into a positive statement that there is no employer in the sugar industry, nor, I believe, in any other responsible and important industry of the Territory, who does not earnestly desire to employ citizens of Hawaii, in preference to those who come from outside our boundaries, be they citizens of the United States, Filipinos or aliens.

With equal emphasis I assert that preference is and always will be given to the employment of citizen labor and present residents of our Territory above all others, such preference and employment being always subject to the suitability of those available for the tasks in question and to their readiness and willingness to undertake them.

Quotation from the address of F. C. Atherton in 1931 as retiring president of the Hawaiian Sugar Planters' Association:

As you all know, definite assurances have been given to these people (i.e., young people growing up here), the great majority of whom are citizens, that they will be given every opportunity for employment, and as far as practicable in skilled and semi-skilled positions as same are available, and they are qualified to fill them.

There are jobs available every year on our sugar plantations; there are young men growing up in Hawaii to working age each year; there is a sincere desire on the part of those responsible for the operation of the sugar industry to attract local young men to plantation jobs; and there is a sincere desire on the part of a great majority of local young men to get and keep steady jobs. All of these statements are true and still we have difficulty in bringing together the local young man and the plantation job which is available for him provided he is ready and willing to take it.

Why should this problem exist? Demagogic political office seekers, striving to gain votes by any means, assert that it is because the plantations want "cheap Filipino labor," while other misguided, misinformed or designing persons say vaguely that it is because we have not tried honestly to make agricultural jobs and rural life attractive to local young people. Such statements and others of

* Presented at eleventh annual meeting of Association of Hawaiian Sugar Technologists, Honolulu, October, 1932.

similar purport may properly be dismissed with the emphatic statement that they are untrue.

I feel sure that your president in assigning this subject to me had the same thought in mind which I had in accepting it, namely, that no useful purpose would be served by taking up your time in refuting untrue and unfair statements such as those quoted above.

It is, however, worth while to analyze the problems involved in this matter, to show some of the accomplishments which mark the progress thus far made toward their solution, and to attempt to formulate constructive lines for future work.

As members of this Association, closely identified with the work of the sugar plantations of Hawaii, we know that the problem of bringing together the local young man and the plantation job has its roots in such matters as the following:

(a) The distribution of population in relation to the distribution of available jobs;

(b) The co-operation of the schools and industry;

(c) Reasonable provision for training and guiding young men through the period of adjustment to the change from school to work;

(d) The provision of every reasonable opportunity for local young men who have taken plantation jobs, to qualify for, and when qualified to receive, as openings occur, promotion to skilled, semi-skilled or "preference" jobs, or other opportunities for advancement within the organization, for which the person in question may be duly fitted;

(e) Attitudes toward plantation jobs of some among the local young people, their parents and members of the plantation organization with whom they come in frequent contact;

(f) Various social factors.

We may first consider the distribution of population and employment, using as bases the figures of the United States Census of 1930 and data collected by the Hawaiian Sugar Planters' Association.

TABLE I

Total Population

(Figures from U. S. Census, 1930)

Territory of Hawaii:	
Population, 1930	368,336
Population, 1920	255,912
Increase	112,424
Increase over 1930	43.9%
City District of Honolulu:	
Population, 1930	137,582
Population, 1920	83,327
Increase	54,255
Increase over 1920	65.2%

The population of the city district of Honolulu in 1930 had increased by 65.2 per cent over the census figure for 1920, while the population of the entire Territory during the same period had increased by 43.9 per cent. The population of the city district of Honolulu was 32.6 per cent of the entire Territory in 1920, and 37.4 per cent of the total in 1930. There has been during the decade an extremely rapid increase in the number as well as the proportion of city dwellers.

TABLE II

Persons Gainfully Employed, by General Division of Occupation—10 Years of Age and Over
(Figures from U. S. Census, 1930)

Occupation	1930 Census Number	1930 Census Per Cent of Total	1920 Census Number	1920 Census Per Cent of Total	Change in Number Engaged Increase	Change in Number Engaged Decrease
All occupations	154,270	100.0	111,882	100.0	42,388	
Agriculture, forestry, and animal husbandry	65,692	42.58	56,244	50.30	9,448	
Manufacturing and mechanical industries	21,028	13.64	18,194	16.20	2,834	
Public service (general)	21,387	13.87	6,282	5.60	15,105	
Trade	13,141	8.52	7,343	6.50	5,798	
Domestic and personal service	12,595	8.16	8,466	7.60	4,129	
Transportation	10,780	6.98	7,781	7.00	2,999	
Professional service	8,533	5.53	4,117	3.70	4,416	
All other	1,114	.72	3,455	3.10	....	2,341

	1930 Census Total	1930 Census Male	1930 Census Female	1920 Census Total	1920 Census Male	1920 Census Female
Total population	368,336	222,640	145,696	255,912	151,146	104,766
Gainful workers	154,270	136,460	17,810	111,882	97,619	14,263
Gainful workers in per cent of total population	41.9	61.3	12.2	43.7	64.6	13.6

There has been a marked increase during the ten-year period in occupations which are largely in the city districts of Honolulu and Hilo, such as Public Service, Trade, Manufacturing, Domestic and Personal Service. These five classifications account for an increase of 32,282 persons, or 76.2 per cent of the total increase of 42,388 persons, gainfully employed.

The number in agriculture, forestry, and animal husbandry, in which 42.58 per cent of all persons gainfully employed were still engaged in 1930, had increased by only 9,448 individuals during the ten years. Therefore, although almost one-half of all people at work in 1930 were engaged in agriculture, forestry, and animal husbandry, they account for only 22.3 per cent of the increase in total workers during the preceding ten years.

The decade 1920 to 1929 was a period of unusual expansion and activity in the cities, especially Honolulu. Public and private building of all sorts was carried on at an unusual rate, governmental service was enlarged in scope, the canning industry expanded rapidly, and transpacific shipping increased considerably, bringing in its train the growth of various lines of business. This rapid develop-

ment has been the cause of the unusual increases in city population and employment which have occurred during the decade. Numbers of people from the rural districts were attracted to the city, and they as well as most of the young people in the city who attained working age during this period found employment in city work, many of them in contracting and other lines where work is intermittent. The ambitions of many young people growing up in the rural districts were drawn to city employment, which, due to the unusual conditions above mentioned, was made to appear attractive.

The present conditions have not only caused unemployment among city workers, but have made it apparent that even after the present situation has passed some part of the young men now growing up in the city will probably have to seek employment in the rural districts in agricultural work if they are to find steady employment.

Meanwhile the number of employees on sugar plantations has remained about constant during the past few years, as shown by the following figures:

TABLE III

Employees on Sugar Plantations
(Figures from H. S. P. A. Records)

Year	Number of Employees
1928	54,437
1929	53,587
1930	53,304
1931	53,960
1932 (7 months)	53,253

EMPLOYEES ON SUGAR PLANTATIONS IN RELATION TO TOTAL GAINFULLY EMPLOYED

Total gainfully employed (U. S. Census, 1930)	154,270
Employees on sugar plantations (H. S. P. A. Records, 1930)	53,304
Employees on sugar plantations in per cent of total gainfully employed	34.6

CITIZEN EMPLOYEES ON SUGAR PLANTATIONS
(Figures from H. S. P. A. Records)

Average for first seven months of 1932	8,391
Citizen employees in per cent of total employees, for first seven months of 1932	15.8

The sugar industry employs directly on plantations more than one-third of all gainful workers in the Territory. Citizens in the number of 8,391 constituted 15.8 per cent of all plantation employees as an average for the first seven months of 1932, and their numbers are steadily increasing.

The records of the Hawaiian Sugar Planters' Association show that for the past few years there have been between 12,000 to 14,000 departures per annum from pay-rolls of all sugar plantations. However, a large number of these represent transfers from one plantation to another. The net requirements of sugar plantations are probably between 6,000 and 8,000 new employees a year as

replacements of those dropping out of the working community for all causes, including return of Filipinos to their native islands.

How many local young men will be available as potential candidates for these replacements of vacancies, provided they are ready and willing to take the vacant jobs? The census figures give the total number in each age group, of whom, of course, only a part could be considered as available for plantation work.

TABLE IV

Population by Year of Age in 1930

Age in Years	Male	Female	Total
1	4,948	4,702	9,650
2	4,896	4,802	9,698
3	5,087	5,037	10,124
4	4,708	4,427	9,135
5	5,257	5,134	10,391
6	4,911	4,936	9,847
7	4,672	4,484	9,156
8	4,605	4,415	9,020
9	4,449	4,256	8,705
10	4,374	4,092	8,466
11	3,913	3,809	7,722
12	3,850	4,024	7,874
13	3,698	3,495	7,193
14	3,400	3,387	6,787
15	3,268	3,115	6,383
16	3,175	3,069	6,244
17	3,145	2,850	5,995

In considering plantation jobs, we are concerned with the males shown in the tables, and with their distribution as between rural and city districts. The census does not show the residence by single years of age, but does show it for an age group as follows:

TABLE V

Distribution by Counties and City Districts of Population, Ages 5-14

	Total Population Ages 5 to 14 Inclusive		
	Male	Female	Total
Hawaii (less Hilo)	6,433	6,162	12,595
Oahu (less Honolulu)	6,488	6,256	12,744
Kauai	3,932	3,899	7,831
Maui	6,748	6,780	13,528
City District, Honolulu	16,800	16,510	33,310
City District, Hilo	2,603	2,550	5,153
Totals	43,004	42,157	85,161

During the ten-year period in which the boys who were from 5 to 14 years old in 1930 grow up to working age there will be a total of 4,300 a year, of whom

1,680 are in the city district of Honolulu and 260 are in Hilo, making a total of 1,940 a year in cities, and 2,360 a year in rural districts.

It is, of course, a fact that in no one year would all the boys of one age go to work, since they would start at various ages from 15 up to over 20. However, the variation between yearly age groups over a period of a few years is so small that we may probably assume without grave error that the total number of young men who will enter work in any one year will be about equal to the mean number a year for the period.

If 60 per cent, which is a proportion never yet approached, of the 4,000 or so young men who enter work each year were to go onto plantations, this would be 2,400 a year, or about one-third of the number of replacements normally required, as shown by the records of the past few years. This number, however, would involve a considerable movement of city boys to the country, a development which cannot be forced and which even with gradual growth presents difficulties either in Hawaii or elsewhere in the United States.

The foregoing figures and statements have shown that there is no dearth of potential openings for our 2,400 new entrants upon work, provided they are ready and willing to take the jobs which are available. There are, however, real problems due to the distribution of population in relation to the distribution of jobs by localities.

Table II (above) shows that for several years the number of employees on sugar plantations has been between 53,000 and 54,000. How are the 53,000 jobs distributed by classifications of work? The following table, which gives this information for an irrigated plantation, gives an indication of the answer to this question:

TABLE VI

Average Distribution of Employees on an Irrigated Sugar Plantation

	Number	Per Cent of Total
Field work, automotive department, railroad and experimental department	2,355	77.6
Factory, electrical department, laboratory and shops	302	10.0
Pump department	113	3.7
Carpenter and building department	84	2.7
Civil engineer's department and mountain water system	98	3.2
Office	5	.2
All others	80	2.6
Total	3,037	100.0

Dividing the figures in another way it is found that there are a total of 490 skilled, semi-skilled and "preference" or "prestige" jobs other than long term cultivation contractors, 915 long term contractors, and 1,632 in all other labor classifications.

It will be noted that almost 80 per cent of the jobs are in the field and its associated departments.

Assuming a somewhat similar division for the 53,000 employees of all plantations, there would be about the following numbers in jobs:

Field work and related departments	41,500
Factory, shops, etc.	5,300
Water supply engineering, construction and miscellaneous	5,300
Office	110
All others	790
Total	53,000

The division of the new openings for replacement jobs will not correspond proportionately to the above classification by kinds of work, because the turnover is always highest among the rank and file of manual labor, and decreases rapidly and progressively through to the semi-skilled and skilled employees, and those in the supervisory grades.

If we assume 7,000 vacancies a year it is probable that about 5,700 of them would occur in field labor and cultivation contractors, 700 in all other labor, and 600 in semi-skilled and skilled jobs. However, a large part of the semi-skilled and skilled jobs must necessarily be filled by promotion of those citizens who have qualified for them, usually by starting at the bottom as a laborer, or as one of the limited number of apprentices who can be taken on for the various trades.

Therefore, of the 2,400 local young men we have heretofore deduced as being the maximum we might think of as entering plantation work in each of the next ten years, only a few of the best qualified could hope to enter immediately upon "preference" or "prestige" jobs, and the great majority would start at the bottom in the field.

An attempt has been made in the foregoing pages to present realistically the facts pertaining to the distribution of population and of employment opportunities, with special reference to sugar plantations.

It is apparent that any attempt to deal with the employment of local young men in material numbers on the basis of their entering only upon "preference," semi-skilled or skilled jobs when beginning work is foredoomed to failure because of the very limited number of such "preferred" openings, of which only a few could be filled by a beginner.

It is equally apparent, on the other hand, that the numbers of local young men who will be available within the next few years are utterly inadequate to supply all of the replacements required by sugar plantations, even if all of them were ready and willing to take the jobs available.

Therefore it will be necessary to bring together the local young man and the plantation job which is available for him, recognizing that it will be necessary in most cases to start at the bottom in field work. If our program of cooperation is not one which has a reasonable possibility of bringing this about, then it is foredoomed to failure. The progress which has been made, however, indicates that there is cause to feel confident that in time it will be increasingly successful.

The closer cooperation which is developing year by year between the schools and the agricultural industries has been productive of good results which will

increase as time goes on. School and home gardens or similar projects have interested children in growing things. Smith-Hughes classes in vocational agriculture when properly planned and carried on have usually been successful in acquainting boys with the nature of field work and giving preliminary training in its performance. A number of young men are successfully employed on plantations today because their interest in the work was aroused in such classes. A further development is the experimental Continuation School for boys regularly at work which is being carried on this year in one plantation community. Each of the boys enrolled attends school for 4 hours on one day a week, which it is planned to continue for two years.

Valuable as such work carried on jointly by the schools and industry unquestionably is, it cannot eliminate the necessity for adequate provision for training and guidance of boys and young men during the period of adjustment from school to work through which they pass in their first few months in regular employment, especially in field work.

Such a training program which has worked out well in practice is the formation of a "Citizen's Training Gang," which is entered by all local young men newly employed for field work. Here the youths work in the regular group piece work gang organization, at the usual piece work rates, and all in the gang share on an equal basis in the group earnings.

The Citizens' Training Gang works over the whole gamut of field operations, so that there is opportunity to learn how each of them should be done in order to make a good job. It is especially important to select the right type of luna, having qualities of leadership, fairness, thorough knowledge of the work, ability to teach how the work should be done, and a genuine interest in the boys and the objects of the training work. The young men in training are in constant, daily contact with the luna, and his attitude toward the work, and his manner of dealing with the youths under his charge will have a great influence on the attitude developed by them as well as their progress in learning the work.

The maintenance of order and discipline and insistence on performance of work up to an acceptable standard should be the same as in any gang, because there is no use in postponing the time of realization that work is serious business to be seriously done. However, in administrative relations with members of the Training Gang it should be borne in mind that they are youths in training and not mature men.

The sincere and continuous interest of the head overseer and section overseers in the training program is essential to its success.

After a stay in the Citizens' Training Gang varying from a few months to a year, depending upon the age and physique of the youth and his aptitude in learning the work, he goes into a long term cultivation contract or one of the field group piece work gangs, fully able to hold up his end of the work, often better versed in the work than his fellow-workers in the gang to which he goes, and sharing in the group earnings on a "man-basis." Usually his morale is high, and there is an excellent possibility that he will stick and get ahead in his work.

Consider as an alternative the situation of the inexperienced youth who, newly entering work, goes directly into a field gang without preliminary training. The

work is strange to him and he is awkward in performing it, probably being the butt of joshing by his fellow workers. It is a jolting jump from the schoolroom to work under any circumstances, and more so if, due to some attitude, he may have absorbed in school, he at first considers the work beneath that which he should do. He has to work for some time at a "boy-differential" in earnings. Except in the case of a few of the most capable and determined youths, there will be a rapid lowering of morale, a development of dissatisfaction and the probability that he will quit his job and may possibly wind up a loafer or worse.

Some may say that the individual should develop his own initiative and determination to work, and manage to get his own training. Theoretically that may be true. Practically we want results in terms of numbers of local young men successfully established in plantation jobs, and we should take the necessary steps to go more than half way in bringing together the local young man and the plantation job.

The plan of training described above is one which has worked out in practice, but it is recognized that considerable variation may be desirable in fitting the methods to the conditions existing on various plantations.

The important thing is that there shall be a systematic plan of training and guidance through the period of adjustment from school to work, and that it be given the continuing interest and supervision of the plantation management and staff.

The local youths who have qualified by ability and demonstrated willingness to work at the starting jobs, usually in the field, which are available, should be promoted to the skilled, semi-skilled and "preference" jobs *for which they are fitted,* whenever vacancies occur in such promotional jobs. It is, of course, understood that the local young man in order to secure promotion must be capable of filling the advanced job, for which he must have qualified by his past work record and length of service. Personnel records which can be used for reference in such cases are advisable.

No one would advocate displacing capable and faithful semi-skilled or skilled workers to make way for local young men. However, when a vacancy occurs in such a job in any department, every effort should be made to fill it by promotion of a local citizen who has qualified for it, and, if possible, by one who has started at the bottom in the field. Earned promotions, made according to a consistent plan, are a powerful magnet in attracting other local young men to enter plantation jobs.

The attitudes toward plantation work of some of the young people, some of their parents, some school teachers and some in other elements in the community add to the problems involved in bringing together local young men and the plantation jobs which are available for them. Attitudes cannot be corrected by condemnation. They can only be changed by a long and patient course of continuing to carry on our affairs in such a way that the right attitude should be developed thereby in any reasonable person, and by combating and correcting wherever they are found erroneous statements or ideas which might contribute to the formation of wrong attitudes. More often than not, it will be found that an attitude of

prejudice against plantation work is due to ignorance of working and living conditions on plantations.

While mentioning the problems created by the attitude of some of the young people and others it should be borne in mind that many of them have an excellent attitude toward plantation work, especially if there is the proper method of approach to them.

I have dwelt in some detail upon the phases of these questions which deal with the young citizen in his relationship to employment in general and sugar plantation work in particular, and some of the advantages which will accrue to the individual and the community as more local young men take plantation jobs, have been pointed out either directly or by inference.

In addition, I want to say emphatically that it is to the advantage of the individual plantation and of the sugar industry as a whole to have as many local citizen employees as possible, and to make every reasonable effort to attract them to the jobs which are available, train them in the work, recognize long service, and, as promotional openings occur, give them preference to the full extent of their qualifications.

The progress which has been made in the industry as a whole shows what can be accomplished by continued effort during the next few years.

It has been clearly demonstrated that local young men in considerable and growing numbers will enter the jobs which are available for them on plantations.

The statistics herein presented to you show that even if a majority of the local young men who attain working age each year should go into sugar plantation work there would still be a shortage in the normal replacement requirements to be made up from other sources in order to carry on the work of the plantations.

The greater number of openings for beginners in plantation work are in field labor, and therefore any effective plan for attracting local young men to plantation work must be laid out accordingly.

Adequate programs for training and for promotion on merit are essential.

The sugar industry of Hawaii employs directly on plantations over one-third of all the workers in all lines of business in the Territory. Having such a large part in the employment possibilities of our local citizens, and recognizing that local young men make excellent workers, it is natural that those responsible for the sugar industry should devote much thought and effort to the stimulation of employment of those who are ready and willing to take the jobs which are available.

Plantation work offers steady, year-round employment at good pay with good working and living conditions. Local young men make highly desirable employees for plantations. The continuation of efforts directed along right lines toward bringing together the local young man and the plantation job will be increasingly successful and will be advantageous both to our young citizens and to the sugar industry of Hawaii.

Improving Field Experiments

By Ralph J. Borden

The value of any statistical method as an aid in the interpretation of results from a field experiment can only be as great as the accuracy and representativeness of the yield figures upon which the method is to be used. No analysis of these yield data, in the office, can correct for the agronomic errors that have been made and the effect of which is already a part of the field results that are submitted for interpretation. High odds that a yield from one treatment is superior to another are of no practical value unless such odds have been determined from accurate data that represent conditions where our recommendations are to have practical field application. With a test properly installed on a truly representative area, our efforts must all be directed in an attempt to secure reliable yield figures that we may interpret.

Representative Areas

Critical studies of field experiments indicate that we can perhaps afford to put more time upon the selection of an area for a field experiment that will truly represent the larger unit of land area to which the problem we are to test will have its practical application. When the yields of the 60 plots of the Hilo Blank Test 58B-1932 were being studied, we were much impressed by the fact that the average yield for the 30 plots in a column adjoining the flume was 97 tons, while the average for 30 adjacent plots of the inner column, that was not 50 feet from the flume, was only 82 tons; in all except one case, 29 out of 30, the plots of the outer column surpassed the yields of the adjacent plots of the inner column. We seriously question the possibility that this outer column of 30 plots represents the average conditions of the field in which it is located. Hence some issues that might be scheduled for testing on the area occupied by this outside column, could not be expected to give us a reliable answer for application to the field. For instance: 200 lbs. of nitrogen might be found to be the economic limit for the strip of 97-ton cane, yet it is conceivable that this amount of nitrogen could be still further increased, with profit, on the 82-ton cane of the inner column.

The situation just described, prompted us to examine our field experiments for similar conditions, and we found indications that we were not dealing with an exceptional occurrence. For instance, let us look at the following:

(1) Experiment 26-30 at Hakalau: 15 plots bordering the trail averaged 55.4 tons of cane. This may be compared with 15 plots, that had the same total treatment, located in an inner column, that averaged 69.5 tons.

(2) Experiment 9-31 at Pepeekeo: 10 plots along the road averaged 74.8 tons; 10 inner plots that are directly comparable averaged 66.5 tons.

(3) Experiment 76-32 at Kilauea: 7 plots in a roadside column averaged 47.3 tons; the adjacent 7 comparable plots inside the field averaged 58.7 tons.

(4) Experiment 2-31 at Kaiwiki: 12 plots on the upper side of the road averaged 68.7 tons; a similar group on the lower side averaged 55.7 tons.

(5) Experiment 6-31 at Laupahoehoe: 15 plots bordering the gulch averaged 65 tons while a comparable group just inside the field produced 82 tons.

(6) Experiment 25-31 at Maui Agric. Co.: The 15 H 109 check plots nearest the camp road averaged 91 tons; the 16 H 109 checks in the inside half of this area averaged 83 tons.

(7) Experiment 44-32 at H. C. & S. Co.: 7 H 109 check plots in one level ditch averaged 84.4 tons; 7 similar check plots in the next-but-one level ditch averaged 102.7 tons.

Further evidence of variation, which makes one wonder which test condition is representative of the major area of the field where the test is located, is offered when we compare the average yield of one series of plots with the average of a similar and comparable series, the two groups being located very close together in the same field. For instance:

(1) In Field 27 at Pepeekeo, a group of 10 "X" plots in Experiment 9 averaged 68 tons of cane, while in the adjacent area, the 10 "F" plots of Experiment 12, that had received identical treatment as the "X" plots of Experiment 9, averaged 77 tons.

(2) In Field 18 at Pepeekeo, a group of 9 "D" plots of Experiment 16 averaged 80 tons of cane; a group of 9 "G" plots in Experiment 17 adjoining, averaged 68 tons. Both groups had received identical treatment. In this same contiguous area 9 "B" plots from Experiment 15 gave 84 tons, and 10 "X" plots from the adjoining Experiment 18 averaged 74 tons. All four of these series of plots had been similarly treated.

(3) In Field 14 at H. C. & S. Co., a group of 7 "C" plots of Experiment 6 averaged 68 tons. This may be compared with a group of 7 "G" plots of Experiment 7, which were similarly treated and located in adjacent level ditches, and which produced an average of 82 tons.

(4) In Field G at H. C. & S. Co. a group of 7 "C" plots from Experiment 11 gave 85.6 tons, as compared with a similarly treated group of 7 "G" plots of Experiment 13 that gave 72.6 tons.

(5) In Field O-8 at Pioneer, a group of 9 "C" plots in Experiment 25 averaged 89.7 tons and a group of adjacent plots, of an NPK test, that had received similar treatment, averaged 76.7 tons.

(6) In Field B1 at Pioneer: 6 "E" plots of Experiment 32 at 84.3 tons had been treated just the same as a group of 6 NPK plots from the adjoining Experiment 33, which made an average yield of 97.8 tons.

From the foregoing examples of differences between various series of plots on closely adjacent areas, one sees the necessity for a careful study and recognition of conditions that might make for such differences, for we must insist that the area selected for our experiments be representative of the average conditions for which it is planned. Thus, we are led into a study of the probable reasons that underlie and cause the plot yields to vary to any considerable extent.

Analyzing the Greater Variations in Plot Yields

In an effort to find more definite evidence of possible reasons for yield variation in field tests, we have examined the 1930, 1931, and 1932 experiments conducted by the Station, and have tabulated all plot yields, that varied more than plus or minus 10 per cent from their treatment average, under the following headings:

1. Border effect.
2. Shape of plot.
3. Adjacent to crop cane.
4. Possibly mixed.
5. Definite fertility zone.
6. Undetermined.

(1) *Border Effect:* Under this heading, we have placed those plots whose deviation of more than 10 per cent from their treatment mean, we felt reasonably certain was caused by their position on or proximity to a road, trail, gulch, ditch, waste area, or to some other factor that would give to their perimeter, a different exposure from other plots in the test area, which might well be responsible for the yield that was "wild" or considerably different from the average.

(2) *Shape of Plot:* Here we have grouped those plots that are wedge-shaped, triangular, or which have irregular outlines, and also plots that carry an extra short (hapa) watercourse. Errors of area measurement or errors due to separating cane at harvest are indicated in such cases. Perhaps these odd-shaped plots are made necessary by changes in contour and such changes carry differences in natural fertility. Perhaps the relative amount of border cane in the average and the abnormal yielding plot, as indicated by differences in the ratio of a plot's perimeter to its acreage, is responsible for the variations we find.

(3) *Adjacent to Crop Cane:* This classification was added as an afterthought when we found that a large number of the so-called "wild" plots were adjacent to crop cane, and there were no other apparent reasons for the deviation from the normal. The reason for same is debatable. Where the situation occurs at the end of a series of test plots, it is possible that the loaders accidentally mixed up the crop cane and the experiment cane of the adjoining plot, perhaps during a moment's suspension of watchfulness on the part of the man checking the loading. Where the end plot of the test area has a high yield, there is a possibility that the plantation fertilizer gang overstepped their bounds and gave the test plot an extra dose of fertilizer. Where the situation is an internal one, it is possible that the original reason for having a plot of crop cane inside the test area may be the cause of the variation of the adjacent plot of experiment cane. For instance: an outcropping of rock within the test area would probably result in a plot of crop cane therefor; it is quite possible that this rock formation may extend under the surface of the ground and affect an area to a considerably larger extent than surface inspection reveals.

(4) *Possibly Mixed:* Whenever we found two "wild" plots adjacent, and one of them was high while the other was low, providing other plots in proximity were normal, we suspect that the cane grown on the two plots has been mixed before it was weighed. Perhaps there is another answer to such a situation, when there is an abrupt change of contour.

(5) *Definite Fertility Zone:* Very early in the study, we recognized the existence of a definite zoning of groups of high and of low yielding plots. We soon found that this was the greatest factor that we would have to deal with. Unfortunately, this zoning is not a factor over which we have the same degree of control that we can have over the four preceding factors, and we are in need

of a practical technique that will locate it. Blank tests have been suggested, to precede the experiment, and they do offer some promise. Soil borings, to determine the uniformity of soil characteristics have been used to advantage in Louisiana. Ample replication of plots does much to reduce the effect on a treatment average that a few plots in a zone of low or of high fertility would have, if there was an uneven distribution of this fertility between the treatments.

(6) *Undetermined:* Under this heading we have placed all other deviating plot yields that were not specific errors and which we could not satisfy ourselves to put into one of the preceding classifications. They form a large part of our total number of "wild" plots and are not understandable. We may only guess as to reasons for their being so different from the average.

Summarizing now, we have found a total of 3155 plot yields that deviate by more than 10 per cent from their treatment average. These are here grouped under the six headings that have just been discussed.

(1)	Border effect	153 plots or roughly	5	per cent of the total;
(2)	Shape of plot.....	87 plots or roughly	3	per cent of the total;
(3)	Adjacent to c.c.....	277 plots or roughly	9	per cent of the total;
(4)	Possibly mixed	117 plots or roughly	4	per cent of the total;
(5)	Definite zones	1987 plots or roughly	63	per cent of the total;
(6)	Undeterminable	534 plots or roughly	16	per cent of the total.

The border effect and the effect of shape are very definitely associated with the "wild" plots of irrigated cane. None of the other reasons for deviation can be definitely set down against the irrigated fields to any greater extent than against the non-irrigated fields: the fertility zoning particularly, being just as distinct on both types of cane.

Summary

Opportunities that are still open to the plantation agriculturist to improve his experiments, are to eliminate some of the possibilities of having plot yields in his test areas that vary widely from the average.

Guard against abnormal yields from border effect by not including in the test, plots that have a border exposure that is materially different from other plots in the test area. Preferably, border the test area with similar conditions: surround it with cane.

As far as possible, avoid areas that require odd-shaped plots. If it is necessary to take an area that includes a few such plots, plant and harvest them as crop cane and not as one of the replicates of a treatment.

If necessary to have plots of crop cane within the limits of the experimental area, be sure that such crop cane area extends over a sufficiently large space to exclude any underground influence from the factor that was responsible for having an inside plot of crop cane.

Assume control of all fertilizing operations on the crop cane adjacent to experimental areas as well as on the experiment itself.

Increase the supervision of cutting and loading and take every precaution to prevent possible mixing. Be especially alert at the borders of the test area where the experiment cane adjoins the crop cane.

Spend more time *in the field* before installing the experiment, using the old and devising new methods for locating, and then avoiding, abrupt changes in fertility, and in getting actual rather than assumed uniformity for the treatments.

New Irrigation Methods*

By L. D. Larsen

The past two years have experienced a more widespread change in irrigation practices than the previous twenty; and the next two years, from all indications, will see still more.

Other field practices have undergone a gradual revolution for some considerable time. Tractors replaced steam plows and mules for plowing. Tractors also replaced mules to a lesser extent for hauling cane and for various cultural operations. Cutting back was abandoned. Stripping was largely abandoned. Field work in general was speeded up and was subjected to more intensive supervision. Fertilizer practices were changed. Harvesting was altered by the introduction of loading machines. The cropping cycle was decreased. Irrigation, i. e., the actual method of applying irrigation water, has, perhaps, changed less than any other plantation operation, so far as the industry as a whole is concerned.

Sporadic and increasing signs of unrest, however, have been evident in irrigation circles for some time. About twelve years ago (as described in *Report of Committee on Cultivation, Fertilization, and Irrigation on Irrigated Plantations for 1921 and 1922)* Kilauea Sugar Plantation Company burst forth with the Modified Orchard or Long-Line system for its plant fields, and the Automatic Cut-Line or *Huli* system for the old ratoon fields.

About the same time, H. W. Baldwin, section overseer at Hamakuapoko, worked out the so-called Herring-bone system of long lines fed from flumes, and also from slip-joint pipes. This system, which in our opinion, still has merit under certain conditions, was also described in the *Report of the Committee on Cultivation, Fertilization, and Irrigation on Irrigated Plantations for 1922.*

In the years 1923 and 1924, Hawi Mill and Plantation Company made extensive installations of the Overhead Sprinkler system. This was followed by Honokaa Sugar Company on a somewhat less extensive scale, and was tried out at quite a number of other places.

In 1928, Koloa Sugar Company developed a distinct modification of the Standard Contour system, very similar to a system long used at Kekaha Sugar Company. It was accompanied by the practice of pushing back the cane in level ditches and watercourses. This system generally known as the Koloa system was grabbed rapidly and became standard on several plantations. (Described in the *Planters' Record* for October, 1928.)

In 1930, Renton and Bond described the Ewa Border or flooding system (as reported at the annual meeting of the H. S. P. A., 1930). This revolutionary system was tried on many other plantations with considerable success.

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* Presented at eleventh annual meeting of Association of Hawaiian Sugar Technologists, Honolulu, October, 1932.

Early in 1931, Wailuku Sugar Company went in wholesale for Automatic Cut-Line irrigation on its ratoons, and started with long lines for plant.

The same year Waimanalo Sugar Company installed its classic replicated Level Ditch experiment with long lines vs. contour and planted a number of fields on the Long-line system throughout.

Gradually, all irrigated plantations began to doubt the infallibility and supremacy of the Standard Contour system. In less than two years' time the Standard Single-Line Contour system has practically vanished. Nearly everyone has changed over to lesser or greater modification of the Standard system, or has gone in for one or another of the various newer systems.

From it all, something useful should evolve. It is not to be expected that one standard system will ever be adopted for the whole industry again, any more than that one standard fertilizer formula can be expected. Local conditions of soil and contour will govern the methods to be used. Each plantation, type of contour and soil will be a study in itself. The supremacy and wastefulness of one standard system has been eliminated, and irrigation methods have become a more interesting and more intensive field of study for the intelligent field man.

When this subject was assigned the writer, it was decided that instead of collecting data from the various plantations, and compiling a paper on what has been and is being done on the plantations, along the line of new irrigation systems, it might be preferable to let the men who are actually doing this work describe to us what is being done.

Letters were therefore written to the various plantations and to members of this Association from the various plantations, asking that some representative or representatives from each place come to this meeting prepared to tell what has been done along the lines of irrigation, what degree of success has been attained, and what plans for future development are under way.

The newer systems, so far as they have been seen, may be classified roughly under two headings:

(1) Modification of the Standard Contour system, and

(2) New systems, entirely distinct from the contour system.

These two classes in turn are subject to numerous subdivisions which we intend to hear about from the members present. In order to make a start, and to approach some unity of nomenclature, the main systems or groups that have come to the writer's attention will be named.

Under the first class or modification of Contour system, we have:

1. The Koloa System,
2. The Two-way System or Come-and-go System,
3. The Cut-Line or *Huli* System.

Under the second group, or systems distinct from the Contour, we have:

1. The Single Long-Line System.
2. The Flooding System,
3. The Overhead Sprinkler System.

Most of these systems have developed modifications and refinements, and it is possible that some other unrelated systems may be put forth. However, we shall see.

In order to keep the discussion from wandering too much, we shall try to take up the various systems and related systems separately.*

KOLOA SYSTEM

Mr. Larsen: Let us first consider and confine our discussion to the Koloa system. This system or something very similar to it has been used at Kekaha for a great many years, as has also the practice of pushing back that is generally associated with it. Koloa plantation, however, has been chiefly instrumental in recent developments in the system and in calling attention to same as a distinct labor saving method, and it has, therefore, become generally known as the Koloa system. Will Mr. Hector Moir of Koloa Sugar Company tell us about this system as they use it?

Mr. Hector Moir: The Koloa method of irrigation, which is the two-side irrigation system, is a great saving over the old one-side system of irrigation both in man days per round and gallons of water per acre per round.

Take one field, of 45.78 acres. Under the one-side system the average men per round for the 1929 crop was 71.32 as compared with 25.60 men per round in the same field for the 1930 crop, under the two-side or Koloa method. A saving of 45.72 men per round. The 1929 crop took an average of 142,377 gallons per acre per round, while the 1930 crop took an average of only 69,896 gallons per acre per round. A saving of 72,481 gallons per acre per round. There was a saving of over 92 million gallons of water in the 1930 crop over 1929 crop for this field.

With this great saving of both men and water per round the plantation was able to reduce the rate per ton of cane paid to the cultivation contractors from $1.05 per ton of cane harvested in the 1929 crop for this field to $0.85 per ton in the 1930 crop.

The average acres per man per round was increased from 1.14 acres per man to 2.02 acres per man.

In the straight-line or long-line system there is an additional saving of men and water. In another field of about the same size of long lines, it took only 10 men per round and they averaged 4.43 acres per day and only used 44,461 gallons per acre per round.

FIELD 6—45.78 ACRES

	Man Days per Round	Average Acres per Man Days	Gallons Total Water per Round	Gallons per Man Days	Gallons per Acre per Round	Inches per Acre	Rate per Ton Cane to C. C.
One-Side System..	71.32	1.14	7,456,536	104,550	142,377	5.24	$ 1.05
Koloa System	25.60	2.02	3,132,147	122,350	69,896	2.56	0.85
Difference.....	45.72 Minus	.88 Plus	4,324,389 Minus	17,800 Plus	72,481 Minus	2.68 Minus	$ 0.20 Minus

FIELD 16—44.34 ACRES

Long-Line System.	10.00	4.43	1,971,400	197,140	44,461	1.64	$ 0.60

The Koloa Sugar Company has 2,898 acres of irrigated land and of this total 265 acres are in long-line system and the rest (2,633 acres) are all in the Koloa system of irrigation. The area in long line is being increased in the very heavy black soil in the Mahaulepu section where good surface drainage is needed.

* Discussion compiled from notes taken by R. E. Doty and Ralph J. Borden, with written notes furnished by some of the speakers.

Mr. Larsen: Will Mr. Sandison tell us about the Koloa system as used at McBryde Sugar Company?

Mr. Sandison: The McBryde Sugar Company's irrigation layout is 90 per cent two-side (Koloa) and 10 per cent one-side.

Under the two-side or Koloa system we have reduced the acre inches per irrigation from about 8.1 to 6, and the acres per man day have come up from a weekly average of .8 to 1.7. The acres per man day vary greatly according to the field, from .9 acre for first water in plant cane to 4.1 in fields where an unlimited quantity of water can be used without damaging a watercourse. Our contract rates have been reduced from 25 to 30 per cent.

DATA FROM McBRYDE SUGAR COMPANY—FIELD 4C, 1930 CROP

Koloa Irrigation vs. Ordinary Irrigation

	Koloa—32.62 Acres		Ordinary Contour—49.18 Acres	
	Acre Inches per Acre	Acres per Man	Acre Inches per Acre	Acres per Man
January, 1929	5.00	2.49	6.53	1
February "	5.12	2.46	6.48	1.07
March "	5.57	1.98	8.85	1.12
April "	5.71	2.38	8.11	1.13
May "	5.60	1.85	8.69	1.07
June "	5.22	1.96	9.47	.97
July "	5.26	2.25	8.17	1.04
August "	5.20	2.00	8.39	1.02
October "	6.83	2.30	8.31	1.49
	49.51 ÷ 9	19.67 ÷ 9	73.00 ÷ 9	9.91 ÷ 9
	5.50	2.18	8.12	1.10
Yield	91.02 tons cane per acre		90.96 tons cane per acre	

With the Koloa system we have averaged 2.75 acres per man day for the 1933 crop.

A modification of the Koloa system, which uses the idea of the one cut-line or U system is being tried.

Contracts of about 10 acres per man are given out as before. When hoeing is completed, the men are taken out and put on other work.

Mr. Larsen: Mr. Kahlbaum—what is your experience with this method at Makaweli?

Mr. Kahlbaum: We have a very indefinite water supply. Our 1931 crop was all grown under the old standard contour system. Our 1933 crop was changed entirely to the Koloa system. This change has doubled the speed of irrigation with only half the number of irrigators. We have a comparison for the first nine months of this year of .74 acre per man using the old system, with 2.0 acres per man with the Koloa system. Our 18-day interval has been cut to 13 days. Contract rates which were set at 8 acres per man have been raised to 12 acres. The irrigators take care of their weeding with very little kokua. Rates have been lowered from 90 cents to 70-75 cents per ton on the 1933 crop under the Koloa system.

For the 1934 crop we have tried a modification of the Koloa system, irrigating 60 feet each way.

Sugar tonnage has increased under the Koloa system but cane tonnage has not.

Mr. Larsen: Will Mr. Danford tell us something of this system at Kekaha?

Mr. H. Danford: Kekaha Sugar Company has used this system for over 40 years on the upper lands. We call it a two-way, four-line system. The irrigator works with two portable panis. He uses koa sticks to support the panis at every fourth line. Pushing back is always practiced. In big cane one man averaged 2 to 3 acres per day. In plant cane we give one irrigation by day work. Up to the third or fourth irrigation we use the two-way, one-line-at-a-time system, then three lines are cut. The amount of water handled

depends on whether the irrigator must hoe weeds and irrigate too. *Mauka* lands may get water as often as eight-day intervals, depending on the supply. An average interval is 15 days. We have 5,860 acres under this cut line method. Over the crop period our average costs are $62.26 per acre; 11 cents per acre per day; $3.29 per acre month. Average man-days per acre: 13.71.

Mr. W. W. G. Moir: A difference between the Koloa and Kekaha systems lies in the fact that in the Koloa system the cane line is lower than the watercourse, and therefore has a "spillway effect." In the Kekaha system the openings to the lines are cut to the bottom, with the bottom of the cane line level with the bottom of the watercourse.

Mr. Larsen: How about this system at Lihue Plantation Company, Mr. Rice?

Mr. P. Rice: We don't like the Koloa system. We use a system like that used at Waipahu: irrigating the lines on one side of the watercourse as we go down from the level ditch, and the lines on the other side as we come back up and finish at the level ditch. We make our lines 72 feet long and on plant cane may irrigate half way from each watercourse or we may irrigate all the way. On ratoons we put a pani in the middle and irrigate to this pani.

Mr. Larsen: How about Makee Sugar Company, Mr. Sloggett?

Mr. Sloggett: We use a system somewhat like Lihue's with 72-foot lines.

Mr. Larsen: What do you do at Pioneer Mill Company, Mr. Willett?

Mr. Willett: We have no Koloa system. We use a cut-line system and with plenty of water in wet weather can do 3 to 5 acres a day by cutting several lines. With a 3-acre inch irrigation, we do one acre a day. We are trying the Waipahu system in ratoons: down and up on opposite sides of the watercourse; eliminating every other watercourse of the old system.

Mr. Larsen: Will Mr. Hoogs tell us about the Koloa system at Wailuku Sugar Company?

Mr. Hoogs: We had 150 acres in the Koloa system in the 1932 crop. Compared with the old system of previous years it increased average covered per man day from .85 to 2 acres. We had a considerable amount of washing in the watercourses except in nutgrass fields. We will change back to the old system where washing is bad.

Mr. Larsen: Mr. Broadbent, will you tell us about this system as used at Puunene?

Mr. Broadbent: We had one-third of our area under the Koloa system and two-thirds under a modified Koloa system; making a total of about 7,700 acres. We had excessive washing with the Koloa system in some places and excessive flooding. In our modified Koloa system, we put opala in the bottom of the watercourse and irrigate down one side and back up the other, similar to Waipahu. We gave 11½ to 12 acres per man on contract at 95 cents per ton. We have cut contract prices 20 to 30 cents per ton with the Koloa system. An experiment comparing the Koloa with the single-line contour system shows 1¾ acres per man day applying 3 acre inches with the Koloa system, compared with 1¼ acres per man day, applying 4¼ acre inches with the single line contour. We keep the nutgrass where we use the Koloa system.

Mr. Larsen: How about Maui Agricultural Company? Is there anybody here from that plantation?

Mr. Lyman: Speaking for Maui Agricultural Company, the Koloa system was unsuccessful and has been abandoned. They are using the standard contour method but trying out other methods where possible.

Mr. Fassoth: Maui Agricultural Company had excessive washing with the Koloa method which required lots of labor to fix up the watercourses. Their land is better adapted to a long-line system.

Mr. Larsen: What system is Waipahu using, Mr. Wolters?

Mr. Wolters: We are using a two-way contour system and have reduced rates 10 to 15 per cent.

The new two-way contour or come-and-go system is the standard practice at Oahu Sugar Company and trials of other systems are in progress. The modifications embodied in the two-way contour system as compared with the old system are as follows: The watercourses are spaced from 70 to 80 feet apart, thus omitting every other watercourse as compared with the old contour system in which lines averaged 35 feet long. Level ditches serve from 30 to 35

lines and straight ditches are placed at convenient distances so as to have level ditches less than 1,000 feet in length.

The cane is irrigated through the full length of line between watercourses until about the fifth or sixth irrigation. The 70- to 80-foot furrows are then divided in half by banks of earth, after which two sides are irrigated from each watercourse. Starting from the level ditch irrigation proceeds down one side of the watercourse and returns upward irrigating the lines on the opposite side of the watercourse and always ending at the level ditch. After the cane lies down the *kuakua* is cut at the central pani and each side of the watercourse is a so-called two-line go-and-come system.

At about the time the banks are installed in the furrows, the cane along the watercourses, level ditches, etc., is pushed back. Cane 6 to 10 feet from the watercourse is pushed first, followed by the cane nearest the watercourse. This insures a good job that lasts since the pressure from the rest of the cane in the line is not great enough to flop it back. The suckers that come up and any growth thereafter is not pushed back as this growth is not recumbent. Pushing back is done following an irrigation or heavy rain when the soil is soft and there is least danger of breaking the cane. We have had indications from fields that have been pushed back on the watercourses of improved juice quality compared with adjoining fields that were not pushed back.

Ratoon fields have been changed over to the two-way contour system by eliminating every other watercourse in ratooning, replanting with the first water the sections of lines crossing the eliminated watercourse.

The efficiency and output of a man has been increased under this modified contour system by amounts varying from 50 to 75 per cent per 10-hour day over the old contour system. The irrigation rounds have been increased with no extra amount of water and the moisture content of the soil has been improved, all due to elimination of losses of water.

A 25-acre experiment was laid out to determine the best distance between watercourses for the new system and checked against the old system using 35-foot watercourses. Distances of 60, 70 and 80 feet between watercourses were used and the 80-foot watercourses have used the least amount of water and the cane looks as well in these plots as in the plots that have used the greatest amount of water.

Mr. Larsen: How about Honolulu Plantation Company, Mr. Fassoth?

Mr. Fassoth: We have never used the Koloa system. We prefer the *hulihuli* system, i. e., go-and-come two-line system with one cut line as practiced at Waipahu. All of our old fields have cut lines.

Mr. Larsen: Mr. Menardi, have you used the Koloa system at Ewa?

Mr. Menardi: We have never used the Koloa system. We have the regular U-system and use *opala panis.* The irrigator works down the watercourse one round irrigating both sides and back up the watercourse on the next round. On plant cane, he averages 1.4 acres per man day.

Mr. Larsen: What is the experience at Waianae?

Mr. Eremeef: Thirty acres were put in with the Koloa system. We found that it washed out our watercourses badly and we have changed to the Waipahu system.

Mr. Larsen: Mr. Butchard, how about this system at Waialua?

Mr. Butchard: The Koloa system washed badly except in nutgrass fields. We are working away from the Koloa system toward a long line and a contour border system. We are using a cut-line system in old ratoons.

Mr. Maze: Has anybody tried tamping to stop this washing?

Mr. Fassoth: We tried some tamping of watercourses in plant fields.

Mr. W. W. G. Moir: Koloa has used lime bags, and tried bitumal, which is, however, too expensive.

Mr. Larsen: What is your experience at Kahuku, Mr. Fisher?

Mr. Fisher: We have 70 per cent of our area in the Koloa system and 30 per cent in long lines. We found excessive wash on the *palis* and put in trash *panis* to check it. On some *palis,* we must change the watercourse on every other crop. This is expensive. We are trying out the Waialua system now. The Koloa system is O. K. in the lower fields. One ditchman handles 120 acres instead of 60 under the old contour system. One man now

handles 15 to 20 acres against 10 or 12 acres formerly. Our biggest saving is a 25 per cent reduction in rates. On the high fields a man is covering 2 to 2½ acres a day; on the low fields he makes 7 to 10 acres.

Mr. McCall: Has pushing back at Waipahu affected the juices?

Mr. Wolters: Pushing back has not damaged the juices at all; in fact we have definite evidence that the juice is better under the Koloa system. The suckers along the watercourse have a better chance to mature.

Mr. Willett: At what age does Waipahu push back?

Mr. Wolters: We push back at 4 to 6 months, after about the sixth or seventh irrigation.

CUT-LINE OR *HULI* SYSTEM

Mr. Larsen: Let us now consider some of the cut-line systems. Various cut-line systems have been used for years—often by the contractors without the knowledge of the plantation management. Two- and four-line cutting has been up for discussion on numerous occasions. Cutting the entire level ditch has also been practiced locally and spasmodically on several places. Pioneer practiced a cut-line system in their steeper fields for many years for the purpose of handling freshet water. They ran some experiments on this which may be of interest at this time.

Kekaha Sugar Company has also practiced cut-line irrigation as a standard practice in some fields for many years.

The automatic cut-line system is a modification of these earlier cut-line systems, designed to automatically control the water entering the lines, and to enable more area being handled per man per day. It originally involved the use of pipes or gates of some sort, but in many cases these have been omitted. Its use on a large scale with pipes was started at Kilauea in 1922 and was continued there until contour irrigation had been entirely replaced by long-lines.

Wailuku went into cut-line as a standard system early in 1931 and since then has put all its ratoon fields into this system in one form or another.

Honolulu Plantation improved the Wailuku system by the use of iron panis and certain other modifications.

The no-water course cut-line system was started as a distinct system at Paauhau in 1931, after which it spread to Kohala where it underwent some drastic changes and then was adopted at Wailuku as the short-line huli system.

Mr. Hoogs, will you tell us about the cut-line system at Wailuku?

Mr. Hoogs: We changed 2,500 acres to the long-line (35 feet) *huli.* For the 1934 crop we have gone into the short lines (17 feet) *huli,* using *pani.* We need twice as many level ditches, with 15 lines per level ditch instead of 30, but have no watercourses in the new system. We get better irrigation. Last year the installation costs on the long-line *huli* were very high because we had to move so much *lepo;* now they are cheaper on the short-line *huli.* We had to enlarge our ditches. The old watercourses were planted up. In plant fields on the *palis* we use pipes from the level ditches. One man can take care of about 20 openings on one ditch. We prefer the distribution of water in two ditches instead of in one. Fields have been carried through for 40 days against 20 days under the older system. The grade of level ditch is .3 per cent. We use no gates; stakes are driven into the ditch and an *opala pani* used.

Mr. Larsen: Perhaps Mr. Bond will tell us about the short-line *huli* used in Kohala?

Mr. K. Bond: The system offers a rapid method of distribution. On steep grades a large stream of water is divided into smaller streams for distribution and short 15-foot lines in the *huli* system are used. This *huli* system is not applicable to flat lands. Longer lines are used elsewhere. We pay 30 to 35 cents per acre against $1.00 per acre under the old contour system. The number of acres per man on plant fields is not set. We give 30 acres per man on long term contract.

LONG-LINE SYSTEM

Mr. Larsen: Since our time is very limited it will be necessary to dispense with further discussion here and consider some of the methods other than contour, such as long-line and border systems.

Years ago, before the standard contour system was developed, irrigation in the Islands consisted of running the water more or less with the slope whether in the cane row or between the cane rows. In Australia the same system was being used in 1929 when I visited there.

The present long-line system uses the same principle with the exception that a level ditch is now used, out of which pipes, gates, or cuts lead the water from the ditch into the cane row—in an attempt to start as many lines as possible at a time. The main difference in the new system is that a large stream of water is used in large supply ditches or level ditches, which enables the irrigator to run a great many lines at one time. Numerous variations have come into effect, of which we expect to hear from you. The original description in 1931 tells of the first field laid out to the so-called Modified Orchard system at Kilauea, and reports 28 acres irrigated per man day, under a most favorable layout. The following year in 1932 a full report is again given in which certain modifications have begun to appear. The principal modification is a deeper line with water running in the cane row, rather than between the cane rows, and contouring along the steeper hillsides.

We should like to hear from a Kilauea representative as to what modification in the system has taken place since that time with them, and what they are doing at present in the way of acres irrigated per man day, water consumption, or any other data they may have to present.

Mr. McCall, will you tell us something of the Kilauea Long-line system?

Mr. McCall: We formerly used a straight line but now it is more of a continuous line which is not too steep but sort of follows a contour. The spacing between lines is 4½ feet. It has been adopted for a cultivation practice in which a furrow opening is made close to the cane. Fertilizer is put in this furrow. We use a sliding (Makee) furrow opener on a cultivator to open this water line and also to cover seed in a plant field. The water line is put on the upper side of the cane row. We have recently used a Stubenberg opener to open this furrow. Over an average of 1600 acres we can irrigate 7½ acres per man day (all fields). In plant fields we do 1½ to 2 acres per man day. For later irrigations, 17 to 18 acres per man day is obtained on favorable land. We cultivate between every irrigation for weed control. Our water consumption is from 2½ to 4.84 acre inches per acre per irrigation, and as low as one acre inch.

Mr. Danford: Kekaha uses a straight line irrigation in the swamp lands where irrigation serves a double purpose of washing out the salt and watering the cane. Our lines run from 100 to 200 feet long. The average man days per acre over the entire crop period is 6.71; the average cost per acre month is $1.66. We have 1740 acres in long-line irrigation.

Mr. Wolters: We have 300 acres on the peninsula coral soils in long line and 60 acres up mauka. Lines are about 200 to 250 feet long and have a fall of ½ to 1½ per cent. Lines should be shorter for slopes less than ½ per cent. We keep the water *in* the cane row. The men cover 2½ times the area with less water than the old system.

Mr. Sandison: At McBryde, we have no long-line irrigation owing to the compactness of our soil preventing an even distribution or the application of an adequate amount. Long-line contour has no advantages for us over a two-side system.

Mr. Fassoth: At Hawaiian Commercial and Sugar Company on the tight red soils we note a low penetration of water with the long-line system. With a slope of 1½ per cent there would be poor cane about three-fourths of the way down the grade. So we put trash panis in the lines to back or slow up the water.

Mr. Menardi: Ewa had the same experience in their borders. We must use trash to slow up the water on a tight soil.

Mr. Willett: Pioneer had the same difficulty of dry spots everywhere in borders on grades of 1 to 1½ per cent.

Mr. Wolters: The length of line must be proportionate to the fall and soil type.

Mr. Larsen: Will Mr. Beveridge tell us of Waimanalo's experiment with long line versus contour?

Mr. Beveridge: In our experiment we gave 17 irrigations with both methods. We have no cost data but have figures as follows:

Method	No. of Level Ditches	Total Acre Inches Applied	Acre Inches per Irrigation per Round	T. S. A.
Long line	6	37.36	2.2	7.01
Contour	6	37.11	2.1	6.41

We have lower costs with the long-line systems and have harvested two plant fields with good results. We have planted some 800 acres to this system during the past year.

Mr. Larsen: In this experiment mentioned by Mr. Beveridge every alternate level ditch for the entire length of the field, was laid out to long lines and every other one to standard contour. The water applied was measured at each ditch. It is noteworthy in the harvesting results that in every case the long line level distinctly outyielded the adjoining contour levels in both cane and sugar.

Mr. Broadbent: Is inadequate moisture at the end of the long line common?

Mr. Larsen: That would depend on the type of soil, the contour, etc.

Dr. Mangelsdorf: Does the upper line in the *huli* system grow better?

Mr. K. Bond: We have not noticed any such difference.

Mr. Denison: Is there any washing in the *huli* system?

Mr. Hoogs: Yes, on the steeper slopes we must use *opala.*

Mr. Larsen: How about installation costs?

Mr. Fassoth: With the long-line system it costs us $3.50 an acre from furrowing to the first irrigation.

Mr. Hoogs: Some comparative Wailuku costs are as follows:

Long-line *huli* planted at $23.00 per acre with 15.3 men per acre (35 feet).
Short-line *huli* planted at $11.00 per acre with 3¼ men per acre (15 feet).
Border system planted at $22.00 per acre with 9 men per acre.
Long-line system planted at $6.58 per acre with 1¾ men per acre.

There is very little *huki lepo* with the short-line *huli.*

Mr. Burnett: Has anyone a satisfactory cultivator for the long-line system?

Mr. Alexander: The light V cultivator used at Kilauea does good work.

Mr. Larsen: Kilauea at present plants flat instead of deep, and starts cultivating right away with ordinary riding and tractor cultivators. When they planted deep in the furrow the "V" cultivator of which Mr. Alexander speaks, was developed and worked very satisfactorily.

FLOODING OR BORDER SYSTEM

Mr. Larsen: We will now consider the Ewa Border system before our time is up. This system was described very thoroughly in a report by Mr. Renton and Mr. Bond in 1930. Since then certain modifications have taken place, chief of which, I believe, is the Aiea Contour Border or Terrace system.

I shall call on the Ewa representative to tell us of further progress, developments, and results since their last report. Mr. Menardi.

Mr. Menardi: We have now had 4 years experience with the border system. We have taken off 5 experiments comparing contour versus border, and have harvested an average of 120.48 tons cane with 14.93 tons sugar from the border against 120.25 tons cane with 14.87 tons sugar from the contour. Two experiments showed the border better than the contour, with significant T. C. A. gains of 3.8 and 6.0 tons, one showed a significant gain of .58 ton and another a significant loss of 1.03 tons for the border. This loss was due to treatment

rather than the system because the border received less water. The border system did not average 4 acre inches per irrigation. This year we are using a double irrigation practice during the "boom stage"; one irrigation of 2 acre inches followed the next day by an irrigation of one acre inch or more. We aim to supply 4 acre inches or more. A small stream on a steep slope does not give an even distribution from side to side of border. Therefore a double irrigation is preferred. The border method uses 7½ to 8 man days per acre per crop.

Mr. Broadbent: In our experiment, we had to give twice the number of rounds in the border as in the contour, because the cane in the border system did not get enough water with the same interval as the contour.

Mr. Menardi: In our experiments, the greatest slope was about 4 per cent. We have used slopes up to 7 per cent in spots but we do not advise such steep grades.

Regarding our weed control in the border system, our costs were too high. This year we have tried different methods of weed control, keeping data on costs and man days required. For fields now closed in the average total cost is $6.62 per acre for the Ewa border system and it has required 5.38 man days. We feel that it will not take over 6 man days or $7.50 per acre with the Ewa border. We are getting away from giving out contracts on plant fields. For irrigation only, for all conditions over an average of 17 months, we average 9.06 acres with the border against 1.47 acres with the contour. With the contour method we need 25 to 30 man days to bring a crop to maturity, as compared with 5 to 6 days with the border, but we must add 6 to 7 man days for weeding. Thus we need less than 15 man days to bring a crop to maturity with the Ewa border.

Contracts are now being given out by blocks rather than by fields. This concentration of water will help to save some of the 13.9 per cent more water that the scattered areas in the border system required previously. We now have 2500 acres in the Ewa border. It has not increased the use of water for the plantation as a whole. In 1927, we were using 10 acre inches per acre per irrigation whereas now we use 7½ to 8 acre inches.

Mr. Broadbent: The average depth of irrigation over the whole plantation has been cut down with the border system. We pay 35 cents per ton for irrigating and weeding.

Mr. Sandison: We have considered some of the newer methods, such as border, contour border, long-line contour, straight line, and a 15-foot-line *hulihuli* system which Mr. Shaw described to us a few months ago, but we are not adopting any of them in the meantime for the following reasons:

1. The topography of our land renders the installation of ordinary border irrigation impossible.

2. We have two acres of contour border and again chiefly for topographical reasons no further installations will be made. We feel that land suitable for contour border should not have a natural slope of more than 4 per cent, while most of our land varies from 6 to 20 per cent. Even at 4 per cent, borders can only be 10 feet apart, and they require nearly the whole of the first foot of soil to make them durable.

Mr. Larsen: I am sorry to note that our extended time limit has expired and it is necessary to end the discussion. I know there are several more representatives present with interesting data on long line, Ewa Border, and Aiea Terrace systems, that we should like to hear, but these will have to wait for another time. By next year there should be more specific cost data available from completed fields, that will show the entire picture of men days and costs at maturity. It should always be borne in mind that irrigation is only part of the picture, and that in looking at any new system the entire cost of growing the cane must be considered. Cost at maturity or men days at maturity is the proper comparison to use from a performance angle.

We have heard references made to drastic cuts in contract rates under one system or another. This also does not show the entire picture. The question at once arises as to how much additional work is done outside the contract and how much of the cut is due to current reductions in general wage rates or expected earnings. Due to increasing yields and a general failure to reduce cultivation contract rates accordingly, long term contractors have in recent years been paid on a more generous scale than other types of field workers. During the wage curtailment program that has taken place during the past year it is noted that this

rather evident discrepancy has been readjusted. In studying the effect of new systems on contract rates and total costs, this general reduction must be borne in mind. A better unit for measuring performance, therefore, is men days per acre or per ton cane for irrigating and weeding combined, or of total men days at maturity. This would give us a truer picture of comparative performance of two systems than can be had from contract rates or even cost at maturity.

Sunlight Hours in Hawaii

Condensed from a Technical Paper by A. H. Cornelison

Is it the amount or the quality of sunlight which has a definite effect on the yield of a Hawaiian sugar plantation? Should not the angle at which the land is exposed to the sun's rays be considered as one of the constant factors which may influence production?

In an effort to stimulate interest in the effect of sunlight in Hawaii a beginning has been made in arriving at the mathematical relative value of an hour of sunlight for summer and winter months on lands of various slopes. The study was made from the point of view of the angle at which the sun's rays strike the earth at these two seasons, disregarding, due to lack of knowledge concerning them, the effects of absorption and reflection on light coming through the earth's atmosphere.

The study is based on the fact that, in the earth's rotation in a slightly elliptic orbit about the sun each year, its axis is never perpendicular to the plane of its orbit. In the northern hemisphere this causes an apparent tipping toward and from the sun in the summer and winter months, respectively. In winter the earth is tipped away from the sun in the north and toward it in the south, while the reverse holds true in the summer. The tipping causes the seasonal variation in temperature and light intensity.

The summer months are warmer in Hawaii because more of the earth's area located on the north side of the equator is exposed to the more vertically falling rays than is true for the opposite hemisphere at the same time: thus more area is getting greater amounts of energy in one case than in the other. In addition, as the earth rotates its varying faces toward the sun, the total time that an area is exposed to the light changes greatly. The mass of the earth at the equator interposes itself and cuts off part of the light that would normally go to the area tipped away from the sun, whereas that tipped toward the sun gets more light, thereby, on its side of the equator. This accounts for the difference in length of day between winter and summer.

An impression may prevail that, though it is colder in winter than in summer, the sunlight would be almost as intense during both seasons were the air not a factor in cooling the area off. This is extremely in error for winter sun is 30 per cent less effective than summer sun so far as energy per unit area of flat land is concerned in Hawaii.

In earlier studies which considered the total sunlight hours alone the fact was disregarded that it is the length of daylight multiplied by its relative intensity that gives us the relative energy received. Thus, while the hours of daylight are longest on June 21, the total energy received is slightly less on this date than it is on June 1 or July 9 because the intensity of the light is higher then than it is on the longest day when the sun is in a more inclined position to the north. For all purposes the hours of daylight from June 1 to July 20 are almost equal

in value for flat land and it is of interest that June 21 is theoretically somewhat less in effectiveness than any other day of the month.

Except for local rainfall conditions, cooler temperatures and possible resulting cloudiness, plantations on steep south slopes will have the effective sunlight periodicity of land lying much closer to the equator and will be subjected to less seasonal variation in temperature and energy received than a plantation on level land in the same latitude.

Plantations on north slopes of more than 3 degrees can never hope to receive full theoretical intensity of sunlight as the sun never reaches a perpendicular above it and also because the declination of the sun behind the interposed land mass makes the hours of daylight shorter, especially during mid-winter months. In this, a third factor is also effective for most north slopes in Hawaii cause condensation of cloud masses that pile up to considerable heights above the land, obscuring the sun through additional degrees of its possible exposure.

Sun spots occurring in 11.1 year cycles are also causes of differences in wave lengths, intensity, electro magnetic disturbance, etc., and the Smithsonian Institute is attempting to determine their values. The variation is not pronounced and is not predictable at present.

Little is known concerning the use of sunlight energy in the life processes of the cane plant. It is generally understood by plant physiologists that several bands of light in the violet and ultra-violet and several in the red and infra-red rays are used. It is believed that most of the bands in the yellow and green are not used, thus causing the green color we commonly associate with plants due to their non-absorption of those rays. The bands in the violet end of the spectrum are very high in energy and are generally considered to be the ones used by the plant in the breaking down of inorganic chemical compounds in the leaf and the building up of extremely complex organic compounds such as sugars, proteins and fats. The effect of the red rays is not definitely known, but they are now being studied by the Smithsonian and Boyce Thompson institutes.

It is also known that when sunlight passes through different thicknesses of vapors, gases and dusts these materials absorb, filter out and in some cases reflect certain colors of light in such ways that the surface of the earth receives only a part of the original rays which enter its atmosphere. These effects are also being studied by the scientific institutions.

It is to be hoped that it will be possible in the future to make a study of the absorption of light by the cane plant and its effects on growth and sugar formation measured in a quantitative way.

It is highly regrettable that at present so little is known of the most important of all of the supporters of life, the sun.

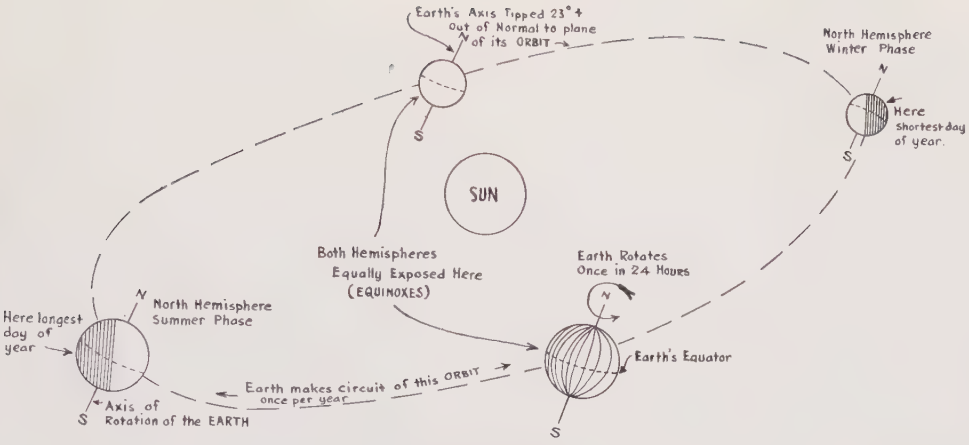


Fig. 1. The four seasonal positions of the sun and earth.

During the earth's rotation in a slightly elliptical orbit about the sun each year, its axis of rotation is never perpendicular to the plane of its orbit. This causes an apparent tipping toward and from the sun in the summer and winter months, respectively, in the Northern Hemisphere.

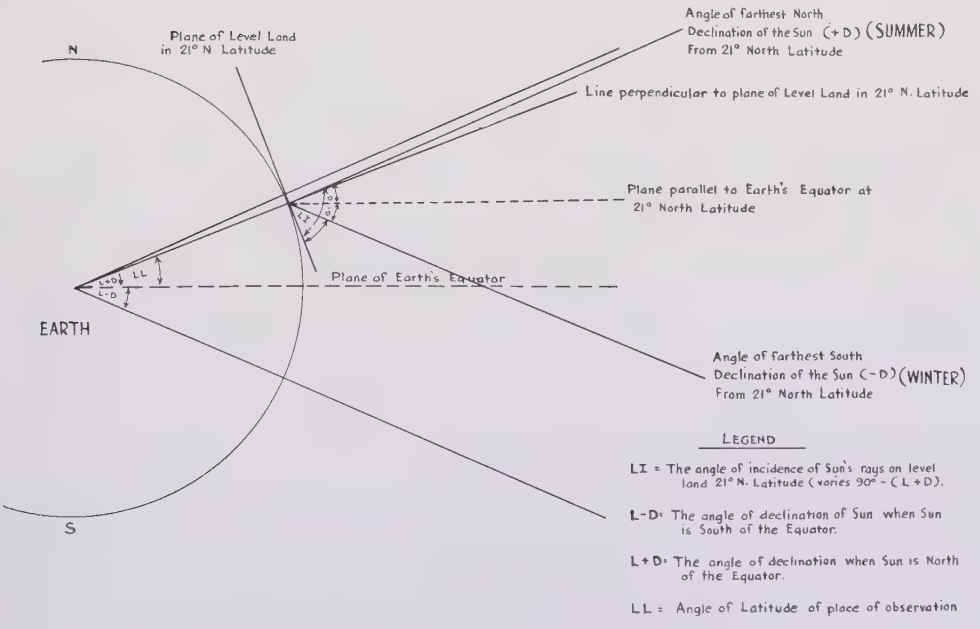

Plane of Level Land
in 21° N Latitude
Angle of farthest North
Declination of the Sun (+D) (SUMMER)
From 21° North Latitude
Line perpendicular to plane of Level Land in 21° N. Latitude
Plane parallel to Earth's Equator at
21° North Latitude
Plane of Earth's Equator
EARTH
Angle of farthest South
Declination of the Sun (-D) (WINTER)
From 21° North Latitude
LEGEND
LI = The angle of incidence of Sun's rays on level land 21° N. Latitude (varies 90° - (L+D).
L-D = The angle of declination of Sun when Sun is South of the Equator.
L+D = The angle of declination when Sun is North of the Equator.
LL = Angle of Latitude of place of observation

Fig. 2. Relative positions and angles of sunlight on the earth.

The Hawaiian Islands, at an approximate latitude of 21° N., receive the maximum intensity of radiation in midsummer, while during the greater portion of the year the sun is angularly coming in at less than perpendicular. The angular difference from one extreme of declination to the other is, approximately, 46°.

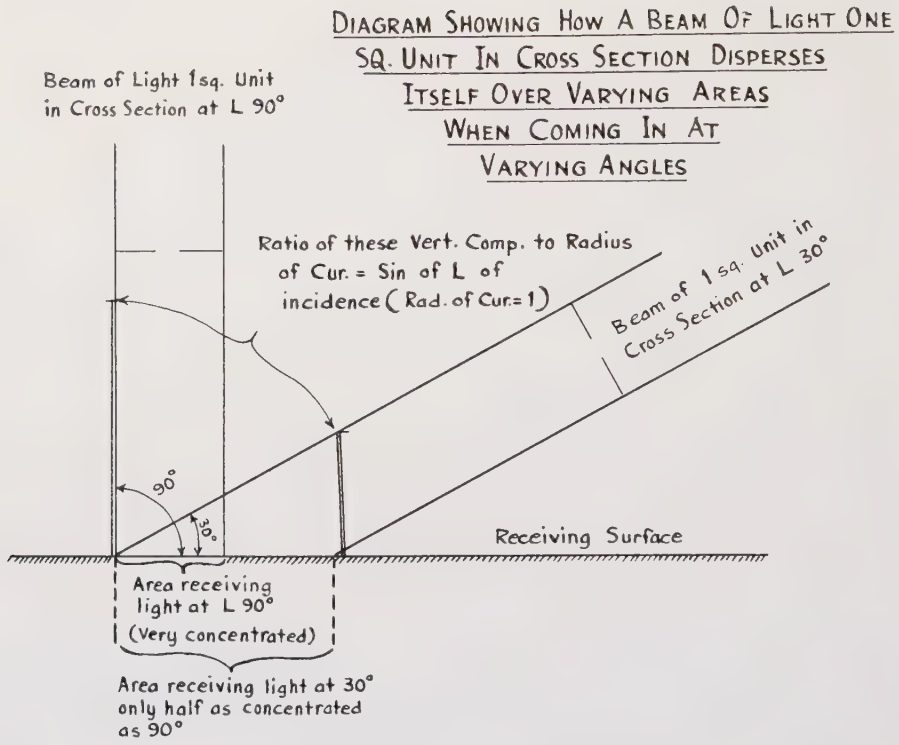


DIAGRAM SHOWING HOW A BEAM OF LIGHT ONE SQ. UNIT IN CROSS SECTION DISPERSES ITSELF OVER VARYING AREAS WHEN COMING IN AT VARYING ANGLES
Beam of Light 1sq. Unit in Cross Section at L 90°
Ratio of these Vert. Comp. to Radius of Cur. = Sin of L of incidence (Rad. of Cur.=1)
Beam of 1 sq. Unit in Cross Section at L 30°
90°
30°
Receiving Surface
Area receiving light at L 90° (Very concentrated)
Area receiving light at 30° only half as concentrated as 90°

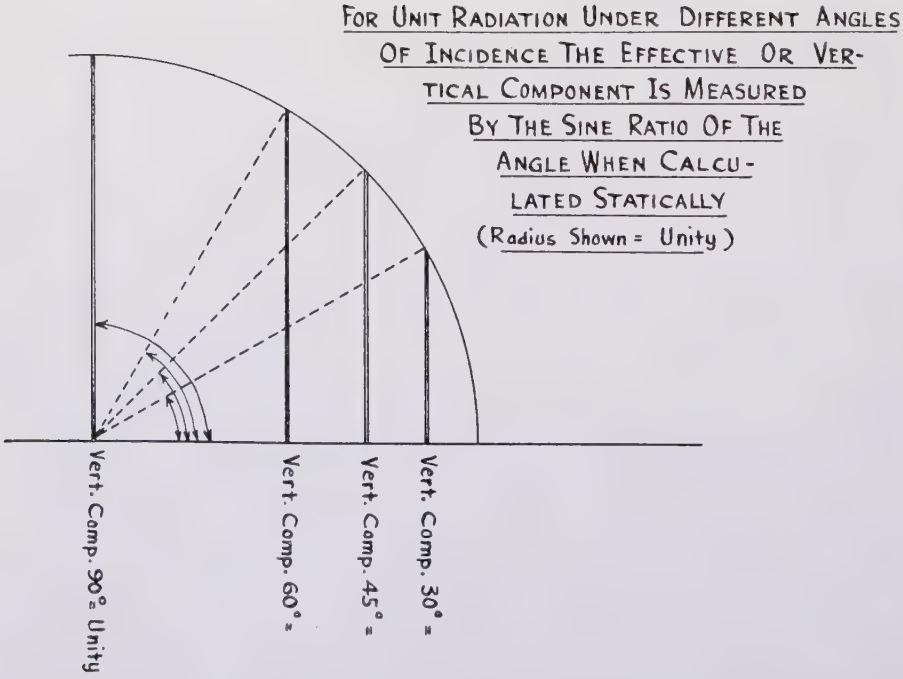
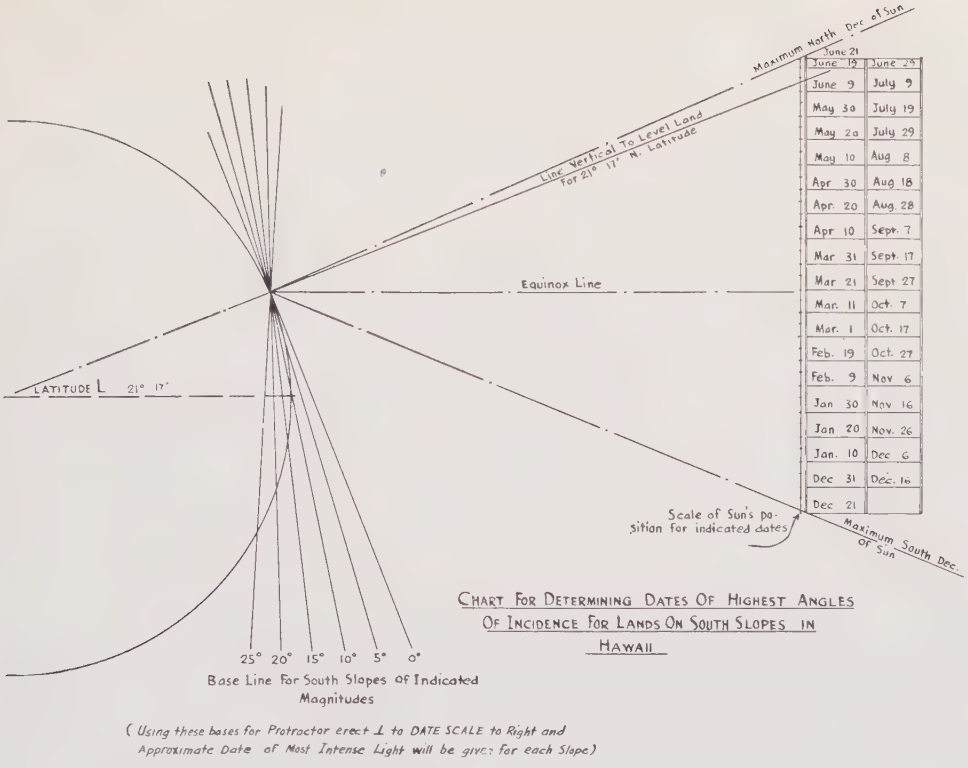

FOR UNIT RADIATION UNDER DIFFERENT ANGLES OF INCIDENCE THE EFFECTIVE OR VERTICAL COMPONENT IS MEASURED BY THE SINE RATIO OF THE ANGLE WHEN CALCULATED STATICALLY (Radius Shown = Unity)
Vert. Comp. 90° = Unity
Vert. Comp. 60° =
Vert. Comp. 45° =
Vert. Comp. 30° =

Fig. 3. For any given beam, the maximum intensity of radiation received will occur as the beam becomes normal to the plane of the receiving surface.


Maximum North Dec. of Sun
June 21
Line Vertical To Level Land For 21° 17' N. Latitude
Equinox Line
LATITUDE L 21° 17'
Scale of Sun's position for indicated dates
Maximum South Dec. of Sun
25° 20° 15° 10° 5° 0°
Base Line For South Slopes of Indicated Magnitudes
(Using these bases for Protractor erect ⊥ to DATE SCALE to Right and Approximate Date of Most Intense Light will be given for each Slope)

June 14	June 29
June 9	July 9
May 30	July 19
May 20	July 29
May 10	Aug 8
Apr 30	Aug 18
Apr. 20	Aug. 28
Apr 10	Sept. 7
Mar 31	Sept. 17
Mar 21	Sept 27
Mar. 11	Oct. 7
Mar. 1	Oct. 17
Feb. 19	Oct. 27
Feb. 9	Nov 6
Jan 30	Nov 16
Jan 20	Nov. 26
Jan. 10	Dec 6
Dec 31	Dec. 16
Dec 21	

CHART FOR DETERMINING DATES OF HIGHEST ANGLES OF INCIDENCE FOR LANDS ON SOUTH SLOPES IN HAWAII

Fig. 4. With the exception of local rainfall conditions, cooler temperatures and possible resulting cloudiness, plantations on steep southern slopes will have the effective sunlight periodicity of land lying much closer to the Equator and will be subjected to less seasonal variation in temperature and energy received than a plantation on level land in the same latitude.

ROUGH CHART SHOWING EFFECT OF CORRECTED SUNLIGHT DATA AS BY LATITUDE OR SLOPE OF LAND

(Actual Positions and Slopes not yet Calculated so Curves are Only Approximations)

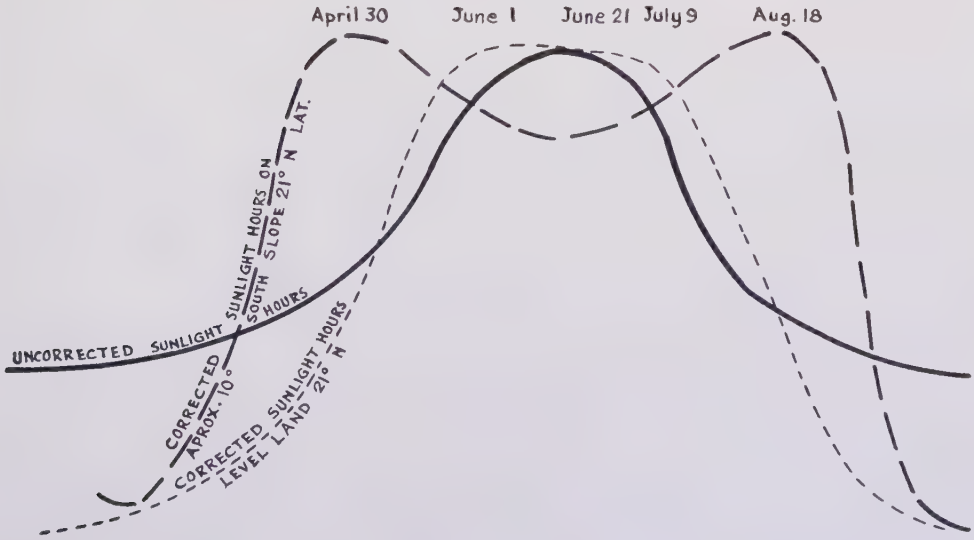

April 30
June 1
June 21
July 9
Aug. 18
UNCORRECTED SUNLIGHT HOURS ON SOUTH SLOPE 21° N LAT.
CORRECTED SUNLIGHT HOURS APROX. 10° SOUTH SLOPE
CORRECTED SUNLIGHT HOURS LEVEL LAND 21° N

Fig. 5. The closer the land affected lies to the tropics of Cancer and Capricorn, the closer together do the two peaks of sunlight intensity fall in the curve; while the closer to the Equator the land lies, the farther the peaks separate.

Beri-beri*

A report from the Customs Department shows that 86,687,461 pounds of clean rice and 763,769 pounds of brown rice are imported annually to the Territory. According to local statistics 4,557,905 pounds of clean rice are produced annually in the Territory. This brings the consumption of clean rice up to 91,925,506 pounds, or a per capita consumption (men, women, children and infants) of 249 pounds. Besides this the Oriental population consumes 87% of the white bread produced. It is hard to conceive of a population consuming such amounts not being definitely vitamin B deficient and definitely acid residue in excess. These are real dietary faults that the future health of our community demand that we give careful consideration.

In a study of the diet of 100 Japanese families in Honolulu in 1929, it was found that a family of six, two adults and four children, used on an average 100 pounds of rice per month. On one of the large plantations of the island the consumption of rice by the Japanese laborers was higher—about 120 pounds per month by a family of six. On the same plantation the Filipinos were found to use still more. A family of four, two adults and two children, used on an average 130 pounds per month.

During that year (1929) 170 babies were born on one plantation, and 29, one year of age or under, died. This is a death rate of 172 per thousand. (The rate for Caucasians last year was 29 per thousand.) Six between one and two years of age also died. Death certificates show that 14 died of pneumonia and eight of beri-beri. In addition to the eight who died of beri-beri, there were 13 others born in this year whose mothers had a history of having had beri-beri. All of the latter were Filipinos. No data on Japanese and other races are available. However, it is very likely that our high death rate from pneumonia is due to the poor condition of the infants resulting from vitamin deficiency.

The dietaries of the families studied in Honolulu and on the plantation are believed to be representative of those of the laboring class of the Territory as a whole. The consumption of 40-50 pounds of rice per month by individuals weighing from 100 to 130 pounds seems enormous, yet 50 pounds per month is not an unusual amount for a plantation laborer. This furnishes on an average 2675 calories per day, which according to Van Noorden's estimate would satisfy the daily caloric requirements of an individual weighing 110 pounds at hard muscular labor. Certainly this amount of rice precludes the consumption of much other food and of course leaves the mechanism functioning with a dietary imbalance. It has been long known that an excess of polished rice in the diet may result in beri-beri. In the Philippines, some doctors believe that a person who eats a pound or more of rice a day can develop beri-beri regardless of what else he claims to eat.

Detailed studies of home conditions, dietaries, and histories of illness of the various members of the families lead to the conclusion that beri-beri is much

* Taken from The Queen's Hospital Bulletin, Vol. VIII, Nos. 5-6.

more common in Hawaii than it appears to be from vital statistics. The disease, in acute form, in adults is easy to diagnose. However, many must be stumbling along close to the verge of acute beri-beri symptoms. One doctor reported a large number of Filipinos coming down with acute beri-beri during a hundred mile hike. They had all started out apparently in fit condition. In infants the symptoms are often not marked, and are not recognized. Frequently there is no history of illness other than a recent loss of appetite with cyanosis or convulsions a few minutes, or perhaps hours, before death. In such cases, if an autopsy is performed, it usually reveals a well nourished infant with no gross pathology. There may be a few suspicious spots in the lungs or a nasal discharge. A diagnosis has to be put on the death certificate, so the baby is "signed out" as a victim of respiratory disease, usually broncho-pneumonia. An investigation of the mother and home is sometimes most illuminating.

The following case was actually investigated and is typical of many. The whole family was under par. The mother had pain in her joints and moved about with difficulty. There was some edema, especially at the ankles, with deep pitting on pressure. Her knee reflexes were not quite normal. Questioned about her diet she said that she did not like milk and vegetables. She ate "plenty" of rice —as much as 40 pounds a month. The baby was breast fed and had never been sick a day until the present illness. He lost his appetite for a day or two and became listless. He did not have any cough, just a little cold with no fever—at least he did not feel hot. Suddenly he turned very pale and gasped. Before a doctor could be found he was dead. This story has been repeated over and over again. Was the malady beri-beri or pneumonia?

Sometimes the baby loses his appetite, becomes listless and may even have a convulsion, but he does not die. The mother decides that her milk does not agree with the baby and gives him a formula. There is almost immediate improvement. The mother feels better too. The next year there is another baby. He looks all right when he is born, but within three days he is dead of "malnutrition."

However, with the large number of dramatic cases as well as deaths known, there must be a greater number who are deficient and on the verge of symptoms. What effect does this inefficient but not incapacitating condition have upon the working effectiveness of a large percentage of the population?

Some doctors who have watched this problem for a number of years have believed that the great vitamin deficiency problem in Hawaii is a lack of vitamin B rather than D. Vitamin D is highly advertised on the mainland and stressed in the scientific literature. It is important in places, but hardly in Hawaii, where 7½ hours of sunshine is enjoyed the year around. (Based on statistics of 20 years.) Dietary studies made thruout Honolulu and rural Oahu, by the Research Department of The Queen's Hospital verify these opinions and indicate the greatest vitamin deficiency in the diet of the laboring class is vitamin B.

Beri-beri is one of the simplest of all diseases to prevent and cure. It has long been known that it never occurs when brown rice, potatoes or poi constitute the chief carbohydrate food. It can be cured and prevented simply by the addition of the polishings of brown rice to the diet. The active principle in the rice polishings which prevents beri-beri is called vitamin B or water soluble B because

of its easy solution in cold water. It was the first vitamin to be discovered. Vitamin B is now known to be a "complex" containing other vitamins as well as the anti-beri-beri one. It is found in fruits and vegetables, milk, whole grains, beans, potatoes and yeast. It is more stable at high temperatures in acid than in alkaline solutions and is not destroyed by ordinary cooking. Among the richest sources are rice polishings, yeast, beans (kidney, navy and soy), asparagus, raw spinach and tomatoes. Proprietary extracts of wheat germ and rice polishings containing vitamin B in various concentrations are used medicinally.

It is well recognized that a deficiency in the diet of any of the essential food constituents results in a deranged metabolism which increases the liability of the individual to various ills. The vitamin B complex has been extensively studied and it is generally agreed that fatigue, lack of muscle tone, loss of appetite and gastric atony are part of the syndrome resulting from a deficiency of this food factor. With the vast amount of information at hand and the means of prevention and cure so easily available, why is it then that beri-beri should be so common in Hawaii?

An infant health center was started as part of our present research project in February, 1930, in an isolated Filipino village on one of our plantations. Two months of intensive effort resulted in the enrollment of a single baby in April, 1930, and much first-hand information in regard to the psychology, living and food habits of the people. With the enthusiastic cooperation of the plantation management, and hospital staff, the health center has grown phenominally in size and influence in the community. There are now two centers, one for the Filipinos and the other for the Japanese, with an enrollment of 110 babies at the present time and a daily attendance of more than 90%.

The total number of babies enrolled during the period of 18 months is 133. Some of these have been discharged because they have reached the age limit (2 years), and others have left the plantation. This large number of babies under daily observation and constant supervision affords a rare opportunity for dietary and clinical studies.

The entire number of babies enrolled is divided into groups, each group receiving specific treatment. Each new addition is assigned to the group that seems best suited to his needs. Milk formulas are prepared according to requirements, every baby having at least one supplementary feeding a day and vegetables, poi, etc., are added according to an age schedule. In addition, certain proprietary vitamin preparations, cod liver oil, yeast and water extract of rice polish are used in certain groups. Control groups are had from those families who do not patronize the health center. Every new born Filipino baby is regarded as a borderline beri-beri case and is given vitamin B in some form on the day of birth, or soon after. One day's delay in beginning treatment, has recently meant the death of two babies under our observation, but not our care.

The necessity of prompt treatment is recognized by many of the parents. Recently a father was at the door of the Health Center at 7:30 a. m. waiting for it to open so that he could register his new son who had arrived at 5 that morning and to get his "kaukau." By 9 a. m. the baby had had his first dose of vitamin

B. This baby is living and thriving—the second survivor of 7 children born to these parents.

As a source of vitamin B a cooked water suspension of baker's yeast has been used in one of our groups. Yeast has also been given to certain expectant mothers who had a history of having had beri-beri. Through the courtesy of the Standard Brands, Inc., an unlimited supply of Fleishmann's yeast has been available for the mothers and babies in this group. In several cases where the prognosis was exceedingly grave, we feel that yeast therapy saved the babies' lives. Of more than 25 babies receiving the treatment, no digestive upset or diarrhea has occurred. During the 18 months the Health Center has been in operation, no baby enrolled has died. Many on admission have been regarded as exceedingly poor risks. No case of clinical beri-beri has developed, nor has any serious case of pneumonia, bronchitis or diarrhea occurred. This may sound like a patent medicine advertisement; however, it is not presented as a cure-all but merely to call attention to the need of more vitamin B on our plantations. Again we wish to emphasize the fact that, important as saving the babies might be, the number who actually die are much less important than the large number who just barely pull thru and become inefficient physical and mental citizens. This is the great load that the Territory must be relieved of.

Growth curves of the Japanese and Filipino babies show that at birth the majority are just as large as the average new born white child. Seven and eight pound babies are common. Until they reach the sixth or seventh month their growth curves closely approximate that of the standard for the American baby, then they begin to plateau and lag and never regain the same growth rate. Experiments on litters of white rats conducted in the Health Center as a demonstration for mothers show identically the same kind of curves, those on a milk, meat-vegetable puree and poi diet, grow rapidly and develop into vigorous animals. Their litter mates of the same size at the time of weaning and subsequently fed on rice and salt cabbage (the principal foods of the Japanese) are permanently stunted in growth.

Babies entering the Health Center after 6 months of age are usually difficult to feed. Their appetites are poor. In many plantation babies of this age, muscle tone is exceedingly poor. It may be, that as in the animal experiments of Cowgill and associates, vitamin B deficiency in the mother's milk has resulted in loss of muscle tone. On the other hand, a number of babies, whose expectancy of life at birth was exceedingly doubtful, have developed amazingly well on mother's milk with a supplementary feeding of cow's milk and vitamin B. Maintenance of the growth rate comparable to that of the American standard for the white child appears to be purely a matter of food, for the first two years at least.

As far as vitamin B is concerned there appears to be no good reason why any person should suffer a deficiency of this food factor in Hawaii and yet facts brought out in this investigation supported by clinical observation, leave no doubt in our minds that a very large per cent of the laboring class is suffering from a deficiency more or less of so-called water soluble B vitamin.

At the conclusion of the survey made on the pre-school children in 1929 an effort was made by us to introduce bread containing rice polish as part of the mid-

morning luncheon in one of the kindergartens, but this was unsuccessful. The United States Department of Agriculture through the Bureau of Home Economics has advocated the inclusion of rice polish in bread and has worked out recipes for it.

From time to time during the past year effort has been made to introduce rice polish into the diet of the plantation laborer, but with little success. A few beri-beri cases have eaten it plain and in every case recovery has been rapid. Mothers have been instructed how to make a mush out of corn meal and rice polish, but this also is not looked upon with favor. A mush of rice polish has also been used at the Queen's Hospital for the treatment of cases.

The present method gives promise of greater success, that is, the addition of the water soluble extract to milk formulas and to the babies' foods prepared in the Health Center, kindergarten and school. A large group of babies and children are at present receiving in this way what is regarded as adequate amounts of this food factor. The potency of the water soluble extract can be determined by animal experiments. It varies with the composition of the rice polishings, there being three layers removed from the rice grain, the middle one of these containing the greatest percentage of the water soluble vitamin. The ease with which the extract is prepared, its palatability and lack of color permit its addition to almost any food that is prepared with water. A further advantage is that it is not destroyed by ordinary cooking.

Finally it is cheap (2 cents a pound at the mill), financially within the reach of the masses.

Progress of the study will be reported from time to time.

If any of the doctors on the plantations have any further evidence or ideas from their experiences with plantation babies, the writer would appreciate hearing from them. How has this problem been handled and what is the minimum which you demand to make the diagnosis of beri-beri either on an adult, an infant, or at post mortem? We would appreciate very much any communications regarding this subject (whether you agree or disagree with the present report).

[D. A. C.]

The Composition of a Cane Crop

By U. K. Das

The sugar cane crop is complex in its composition. At harvest, a crop generally consists of cane of different age levels and probably at different stages of vigor and maturity. Thus in a plant field we may start with one shoot germinated from an eye. This stalk later gives rise to one or more daughter stalks and these latter may produce granddaughter stalks, and so on. The field is harvested, say, at 24 months of age. But how old are the daughter stalks or the granddaughter stalks? What percentage of the total yield can be attributed to these later stalks? What contribution does each of these make to the average juice quality of the whole crop?

For a clearer understanding of the how and why of the final yields, for a true appreciation of the essential factors in crop production, we must begin with a knowledge of the composition of a cane crop and its bearing on the final yield.

With these views in mind, an experiment was installed in the spring of 1931 at the Experiment Station, H. S. P. A., in Honolulu. At this time of writing the experiment has run through approximately 20 months and though it has another 16 months to go, the results obtained to date are thought to be of sufficient interest to warrant their presentation in the form of a progress report. In the following pages, some of the points of more practical interest only are dealt with. A thorough treatment of the numerous and varied data is reserved for the final report.

Layout of the Experiment

The experimental area consists of eight plots, each containing 10 lines, each line being 35 feet by 5 feet. The plots are separated from each other by a path 2½ feet wide. Four plots as shown in Fig. 1 were planted on March 17, 1931, and the other four plots on September 17, 1931. In the first case, the cane started with the spring and summer ahead of it and in the latter case with the fall and winter ahead.

Variety:

Cane—H 109.
Seed—Both body and top seed—three-eye seedpieces.

Fertilization:

With seed { 50 lbs. N per acre from ammonium sulphate.
200 lbs. P_2O_5 per acre from superphosphate.
200 lbs. K_2O per acre from potassium sulphate.

At 3 months—50 lbs. N per acre
At 6 months—75 lbs. N per acre } All from ammonium sulphate
At 12 months—50 lbs. N per acre

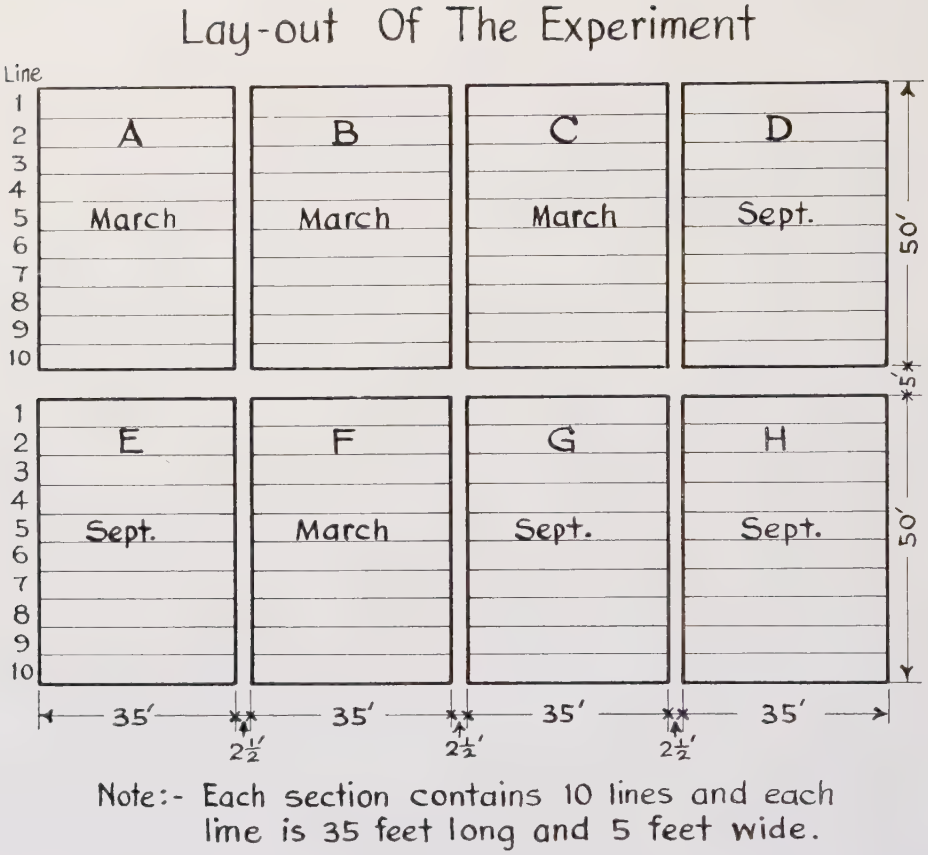


Fig. 1

Thus the total application in each case was 225 pounds N, 200 pounds P_2O_5, and 200 pounds K_2O. These amounts are considered to be optimum under average H 109 conditions on Oahu.

Irrigation: Two inches per application, two applications per week. Allowance was made for heavy showers, light rainfall being neglected. It is believed that 16 inches of irrigation per month represent optimum application of water under the irrigated conditions of this island.

Experimental Procedure

About 35 seedpieces were planted end to end in each row. After about four weeks, the row was thinned out to contain only 35 fairly uniform shoots per line, which gave one shoot per lineal foot of row. This was done to insure a uniform stand of cane in each row. These original shoots, sprung from the seedpieces, are herein called shoots of the first order. Each of these shoots later gave rise to a stool of cane.

These first order shoots were tagged, each tag bearing its serial number, 1 to 35, in each row. Thereafter, at intervals of about two months, we went through the field and labelled all the shoots that had germinated since our previous tagging

and these were successively called the second, third or higher order of shoots. Order in this report, therefore, refers to time of germination only and not to any morphological relationship of one shoot with another.

Suckering

Beginning at one month of age, and thereafter once about every two months, we went through selected rows of cane and counted the number of shoots in each stool. When the cane became too big to render such detailed count physically possible only the total number of stalks in each line was obtained. Particular care was taken not to disturb the growing cane in any way or remove any of the trash from the rows.

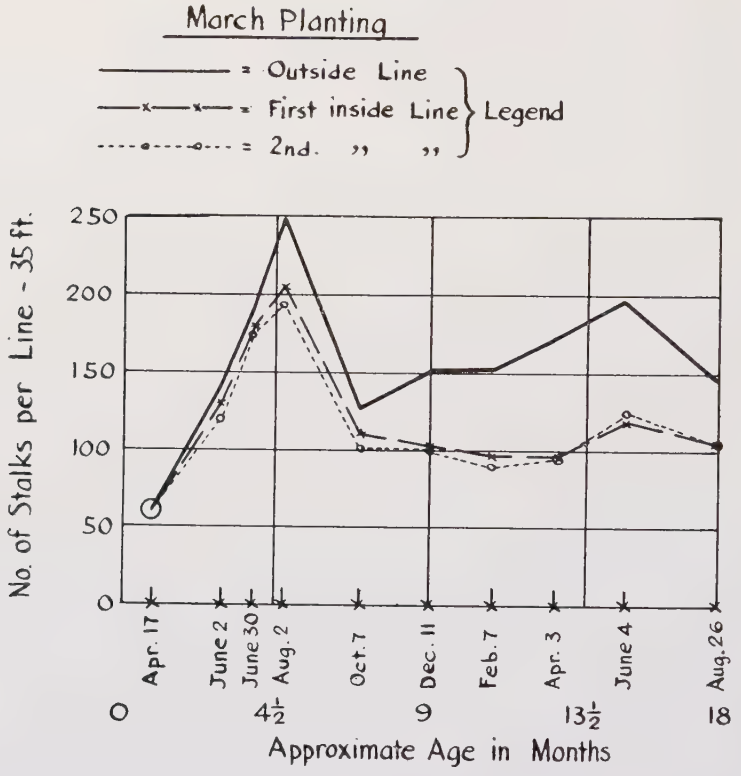
March Planting

Total number of shoots at various ages: Lines 1 to 3 in Sections A, B, C, and F were selected for shoot counts. The total number of lines were 12, representing 420 running feet of row and 420 stools of cane.

The summarized data are presented in Table I and Fig. 2. We see that at about one month of age this plant field of H 109 had only 35 shoots per line, i.e., there were no suckers.* From then on the number of shoots per line increases up to a maximum of about 4½ months of age. This maximum occurs in the early part of August and is followed by a sharp decline continuing through the fall and winter months. There is a little increase in number in the second season spring, but indications are that even this increase will not be permanent.

* In all the following discussions it should be kept in mind that here the original stools were one foot apart to start with. If there were more of the original shoots per foot at the start or if it were a ratoon field, the progress of suckering might have been different.

Number of Stalks per Line on Different Dates - Sec. A, B, C & F



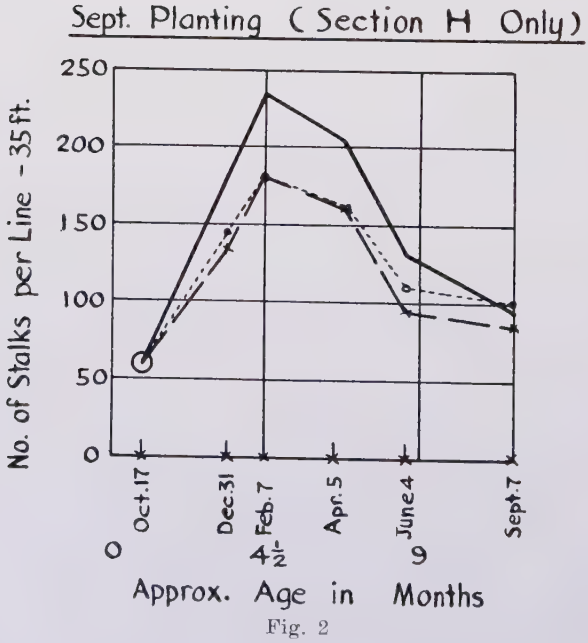


Fig. 2

TABLE I

Total Number of Shoots at Various Dates—Cane Planted March 17, 1931—Average of Sections A, B, C and F

Date	11/4/32	6/2/31	6/30/31	8/2/31	10/7/31	12/12/31	2/7/32	4/3/32	6/4/32	8/26/32
Average of outside lines	35	138	190	249	125	151	150	172	194	146
Average of first inside lines	35	122	173	197	98	100	91	96	123	106
Average of second inside lines	35	133	185	205	110	98	93	97	122	103
Approximate number of months since planting	1	2½	3½	4½	7	9	11	13½	15½	18

September Planting—Section H Only

Date	10/17/31	12/31/31	2/7/32	4/5/32	6/4/32	
Outside line*	35	179	233	207	131	96
First inside line	35	144	181	163	108	99
Second inside line	35	134	179	158	96	87
Approximate number of months since planting	1	3½	4½	7	9	

* It has been explained in the body of the report that this outside line was so only for a short time. As the cane in the adjoining section got big this outside line ceased to be an outside line in the true sense.

Fig. 2 shows only the net results but fails to bring out that in a growing field of cane suckering is a continuous process. Some new suckers are always coming up and others dying, so that the population is never exactly the same, though the total number may remain constant.

In the outside line the progress of suckering is quite different than in the two inside lines. The outside line rises to a greater maximum and the total number does not fall to the level of the two inside lines. Later on in this report we will show that this is due to more space and greater exposure to light obtained by the outside rows.

September Planting

Sections D, E, G, and H were planted in September. At this time, Sections A, B, C, and F had canes already six months old. The end stools in Sections D, E, and G did not get the full amount of sunlight. The shoot count data in these sections are of great interest in showing the effects of shading. However, for the purpose of Fig. 2 only the data from three rows of Section H are summarized, for this is the only section that was not handicapped by the border effect of big cane. The total number of stools here are only 105, but the progress of suckering is identically the same as in the March planting. Starting with 35 stalks per line at one month the number rises to a maximum at about 4½ months and then declines sharply. Contrary to observations reported by others, this decline starts in the beginning of spring and continues through the spring and summer months. Season of planting or season of the year has, therefore, little to do with the general sucker mortality which takes place in every crop. It is also seen in Fig. 2, that in the outside row of Section H, the number of shoots gradually approaches the total of the two inside lines. A study of the layout will show that line 1 in Section H is not an outside line in the sense that line 1 in Sections A, B, or C is. There is only a 2½-foot path separating Section D from Section H. When the cane in Section D got big, line 1 in Section H ceased to have the same space and light as a true outside line.

Factors in Suckering

All evidence points to the fact that suckering is predominantly influenced by light and exposure,* which factors are materially altered inside a cane field by plant competition.

In both plantings, the outside lines have a larger number of suckers than the inside lines. In March plantings, the total number of shoots in the outside lines rises to a maximum of 250 per line or about 7 per lineal foot. In the inside line this is about 5½ per foot. At the time of maximum stooling, the 24 end stools in the 12 lines averaged 9½ shoots per stool but the inside stools averaged only 6 per stool.

The sudden rise in the number of shoots obtained in December for the outside lines of March planted cane is explained by the fact that an adjoining field of cane

* There are indications that it might be the heat that goes with light and exposure more than the photo-chemical effect of light itself that induces suckering.

was cut in October. The outside lines, therefore, received an increased amount of light and space which at once reflected itself in an increased number of suckers in the outside lines.

The inside lines do not show this effect as will be seen from Table II below. Section F, which did not have the benefit of this exposure, also does not show any material increase in the number of shoots.

TABLE II

No. of Shoots on	Oct. 17, 1931	Dec. 11, 1931	Increase or Decrease
Section A—Line 1 (outside)	124	145	+ 21
2 (inside)	102	98	— 4
3 (inside)	97	99	+ 2
Section B—Line 1 (outside)	114	155	+ 41
2 (inside)	91	106	+ 15
3 (inside)	114	106	— 8
Section C—Line 1 (outside)	127	166	+ 39
2 (inside)	99	99	0
3 (inside)	109	93	— 16
Section F—Line 1	135	138	+ 3
2	98	96	— 2
3	118	93	— 25

It has been observed previously that in September planted cane, the end stools in some of the sections did not receive full sunlight. Some were deprived of early morning light and some of afternoon light. These stools show very irregular and delayed suckering compared with the other stools that received full sunlight. Thus, in Section E, in the end stools which did not receive morning light until about 10:00 o'clock, there were no suckers of the second or higher order until after the fourth month. But the point of interest is this: that the same stools caught up with the others in the number of suckers later on. In other words, suckering was not stopped, but only delayed. This naturally raises a question as to the exact nature of suckering. Do the plants have to have a certain minimum or a balance of some essential factors before they will produce suckers? If this condition is satisfied in two months, suckers will start in two months. If it should take six months for the plants to obtain the minimum or the required balance, suckering may well be delayed for six months. The factors may be total quantity of light, heat or some physiological condition within the plant.

The shoot count data in the September planted cane also indicate that the morning sunlight may be superior to afternoon sunlight in the matter of sucker production.

Plant competition: In a field of cane, plant competition has probably a more direct bearing on sucker production than anything else. We use the word "direct" purposely, for the factor of competition brings in its train other factors such as available space, light, heat, etc. Let us consider a plant field that is just started. It has in our case one shoot to a running foot. There is enough space and light

for it to grow and multiply. At first the shoots have small slender leaves occupying small space, but as the shoots become adult or begin to form millable cane—the leaves become broad and big. There is not enough space for all of the shoots to get their share of light. Some of the better placed shoots continue to grow and others are starved, smothered out of existence. This is about the time when we notice the first big mortality in the number of suckers. This fact operates independently of the seasons; for both in March and September plantings, the mortality starts between 4 and 6 months, about the time when millable cane is forming. But in one case this period comes in the fall months and in the other in the spring and summer months.

After the first big wave of mortality there is a period of fairly stable conditions. Those stalks that have survived continue to grow. Then the time comes when the big canes, being top heavy, begin to lodge. The stable conditions are again altered and where the light penetrates the cane rows new shoots spring up. (Perhaps we should attribute this to the heat that comes with light rather than light *per se*.) If the trash covering is heavy these second season suckers may not be very numerous. But, nevertheless, these suckers are a reality. These new suckers get off to an excellent start, and are very soon competing with the old and fallen cane for light and air. In this struggle sometimes the old one, but more often the younger one, survives. It is now the turn of the old cane to begin dying from top downwards. Here begins the commonly observed rotting of the old cane. This picture is well supported by the data on shoot counts and by observations made at the time of harvest.

Number of Stalks per Foot

It will be noticed that both in the March and the September planted cane, the number of stalks per line is about 95 to 100 or about 2.7 per foot. This figure is essentially the same as reported previously by various workers in these islands. But the point of interest is this, that in the March planted cane, the maximum number was well over 200 per line, while in the September planted cane it was considerably less—but at 12 months or at the time of harvest both plantings had the same number of stalks per line. On the one hand, it shows as though H 109 under the experimental conditions can support no more than 2.7 stalks per foot of line: as though the leaves of these stalks fully utilized all the light and air that are available over a foot of soil, leaving no room for further leaf production. (In canes with smaller leaves this number should undoubtedly be greater.) On the other hand, it raises the question: Is it of any advantage to have a large number of suckers to start with if we always end up with the same number? Is the March planting better than the September planting?

Sucker mortality is a natural phenomenon and we shall not possibly be able to stop it, but nevertheless the writer feels that this is at best a necessary evil, that sucker mortality represents much wasted effort and very probably some wasted material.*

* There is some evidence that at least part of the mineral matter may move away from the dying shoots to the growing ones of the same stool. But can this be true of the complex carbohydrates and protein material of the dying shoots?

Border Effect

Fig. 2 shows that a change in the exposure outside of the field affects the outside lines only. Even the first inside lines of March planted cane do not show the fluctuations that the outside lines do. It would, therefore, appear as though one single line of cane was as well able to protect an inside line from extraneous influences as two lines of cane.

Weight of Millable Cane

March planting: Beginning at six months and continuing thereafter at intervals of two months, we harvested two lines of cane. At the time of harvest,

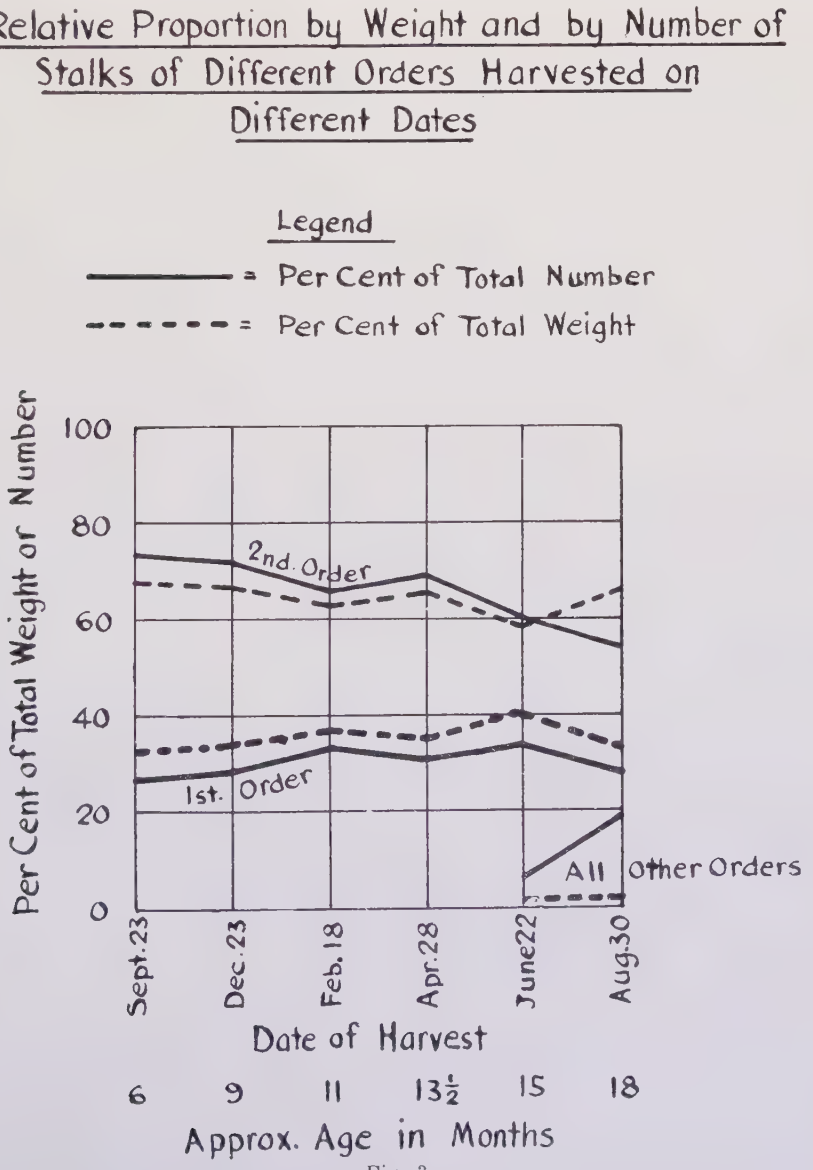


Fig. 3

each stool was cut separately and each stalk weighed, so that we know not only the total weight of cane per row at different ages, but also the relative proportion of shoots of various orders and the weight of cane of each of these orders.

Kind of stalks harvested at different dates: Table III and Fig. 3 show the relative proportion of the different kinds of stalks harvested to date. Here we find that the crops consist almost entirely of the first and second order of stalks. Once in a while we have harvested a stalk of the third order, and more recently a few second season suckers or stalks of the fifth or higher order, but the proportion of the total weight made up by these later shoots has not as yet been of any magnitude. As to the distribution by number, there is in general one stalk of the first order and 2 to 3 of the second order, and perhaps a small fraction of one of the other orders. This picture might have been different with closer planting of the original shoots.

TABLE III

Weight and Number of Stalks of Different Order Expressed as Percentage of the Total Weight or Total Number of Stalks

	1st Order		2nd Order		3rd or Higher Order		
Harvesting Dates	Weight	Number	Weight	Number	Weight	Number	Total
Sept. 23, 1931.....	32.0	27	68.0	73	...	..	100%
Dec. 23, 1931	33.0	28	67.0	72	...	..	100%
Feb. 17, 1932.....	36.3	33	63.0	66	0.7	1	100%
April 28, 1932.....	34.0	31	66.0	69	...	..	100%
June 22, 1932.....	40.0	34	59.0	60	1.0	6	100%
Aug. 30, 1932.....	32.0	28	66.0	54	2.0	18	100%

In other words, most of the cane harvested up to 18 to 20 months consists of stalks that came up within the first three months after planting. This shows that the mortality was almost entirely confined to suckers of the third or higher order.

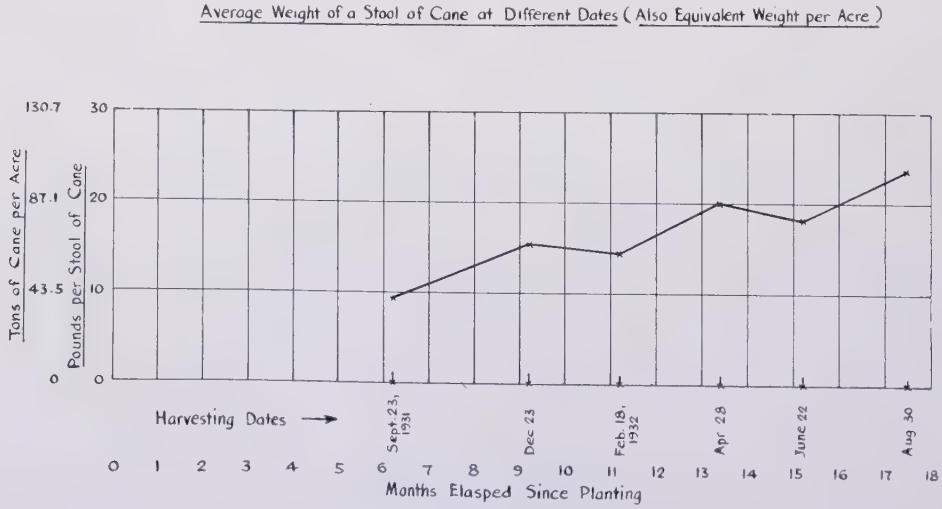


Fig. 4

Weight of millable cane: Since we have in each row 35 stools to start with, we can express the weight at harvest as the average weight of a stool of cane. An idea of the weight per acre can be obtained by multiplying the individual stool weight by 8712.

Table IV and Fig. 4 show the weight of millable cane at different dates. There is a steady trend of increase in weight up to 18 months of age. The fluctuation in weight appears to be entirely correlated with the fluctuations in the weight of the second order stalks, which in turn is correlated with the number of second order stalks harvested at different dates (see Fig. 3). However, these fluctuations are well within the allowable limit of variation to be expected in any field experiment.

TABLE IV

Average Weight of Stool at Different Dates

Harvesting Date	Approximate Age of Field	Average Weight of Cane in One Stool in Pounds	Calculated Weight of Millable Cane per Acre in Tons	Weight of Green Top and Leaves per Stool in Pounds
Sept. 23, 1931.....	6	9.50	41.4	6.40
Dec. 23, 1931.....	9	15.60	68.0	...
Feb. 17, 1932.....	11	14.47	63.0	...
April 28, 1932.....	13½	19.81	86.3	6.93
June 22, 1932.....	15	18.15	79.1	4.37
Aug. 30, 1932.....	18	23.43	102.1	4.411

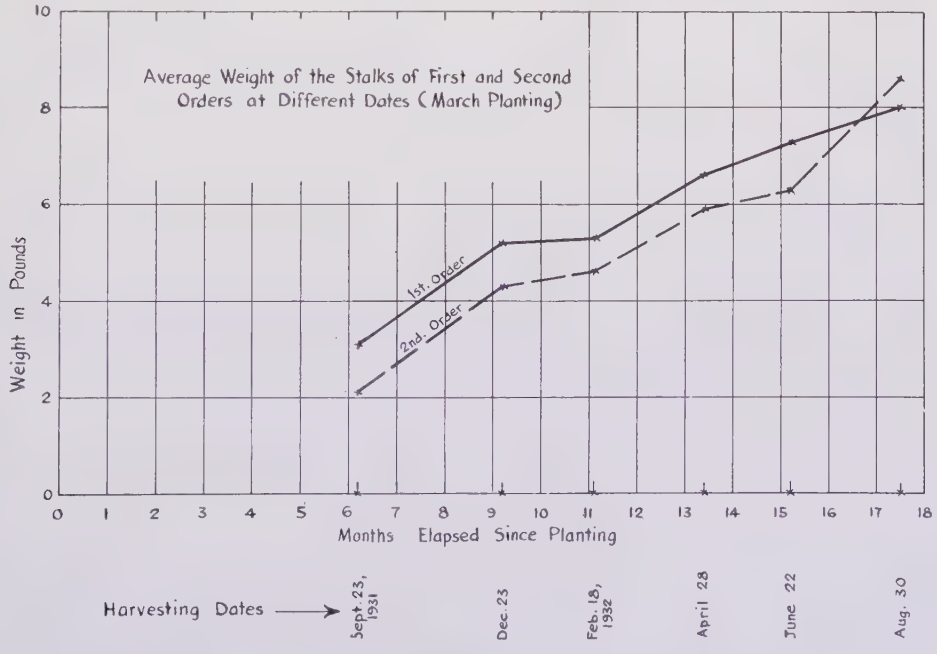


Fig. 5

Increase in weight of the stalks of different orders: Table V and Fig. 5 show the average weight of the first and second order stalks at different dates. It is surprising how regular and how similar is the increase in weight of the stalks of these two orders between different dates. The increases are almost parallel till the fifteenth month. However, the last harvest indicates as though the first order stalks are beginning to slow down, while the second order stalks are still proceeding at a rapid rate. In going through the detailed harvesting data, it is observed that there is greater mortality among the first order stalks than in the second order stalks, which probably accounts for this differential rate of growth. The mortality of the tops of big cane was not in evidence until after the fourth harvest at 12 months. This is to be expected, for this mortality undoubtedly followed the lodging of the big cane at about that age and the consequent shading out by other and more vigorously growing suckers.

TABLE V

Average Weight of First Order and Second Order Stalks on Different Dates

Harvest Date	Approximate Age	Weight of 1st Order Stalks (Lbs.)	Weight of 2nd Order Stalks (Lbs.)
Sept. 23, 1931	6	3.07	2.06
Dec. 23, 1931	9	5.21	4.13
Feb. 17, 1932	11	5.28	4.57
April 28, 1932	13½	6.63	5.90
June 22, 1932	15	7.20*	6.29*
Aug. 30, 1932	18	8.03*	8.63*

But even among the second order stalks there is some mortality after the fifteenth month. Beginning at about that age there will probably be a continuous and mounting loss of cane due to the gradual death and decay of the old stalks. Whether the new suckers will make up for this loss is yet to be seen.

September Planting

We have had only two harvests to date from this planting and, therefore, we need to spend very little time in discussing the results. The data indicate, however, that in Section H (where there were no border effects) the average weight of stool compares well with the weight of the March planted cane at comparable ages. So far there is no difference that could be attributed to season of planting—but later harvest may tell a different story.

It is also of great interest to note that the end stools in Section E (which stools did not receive the morning sunlight) average less in weight at each harvest than the other stools in the line (Table VI). The difference of one and a half pounds per stool in favor of the more exposed stools, as shown by the harvest at 12 months, would amount to a difference of nearly 6½ tons of cane per acre. Will this difference go on increasing as the crop gets older, or will the end plants

* These figures would be higher if the dying or rotting stalks were not included in the average.

overcome the handicap of the earlier months? Right now, most of the canes have lodged and the end plants should have about the same sunlight as the other plants.

TABLE VI

Weight of Millable Cane per Stool at Different Dates

	July 1, 1932	Sept. 8, 1932
Shaded end stools	9.0 lbs.	11.62 lbs.
Exposed stools	10.56 lbs.	13.21 lbs.

Quality of Juice

A study of the composition of a cane crop is essential for an understanding of the factors bearing on juice quality, if for nothing else.

What are the components that make up the average quality ratio of a crop? What is the quality of juice in stalks of different orders? Is second season suckering a real detriment to good juice? In the same cane, how does the top part differ from the bottom part? Where lies the difference in juice quality between a vigorously growing cane and a cane that is slowing down growth and shortening its green vegetative part? These are pertinent questions, but our study of juice quality cannot progress without an answer to them.

At each harvest the stalks of different order were segregated and the juice extracted by a three-roller mill and analyzed. No attempt was made to draw representative samples, but the total quantity of cane was run through the mill. Occasionally one or two extra lines of cane were harvested to gain additional information on some points.

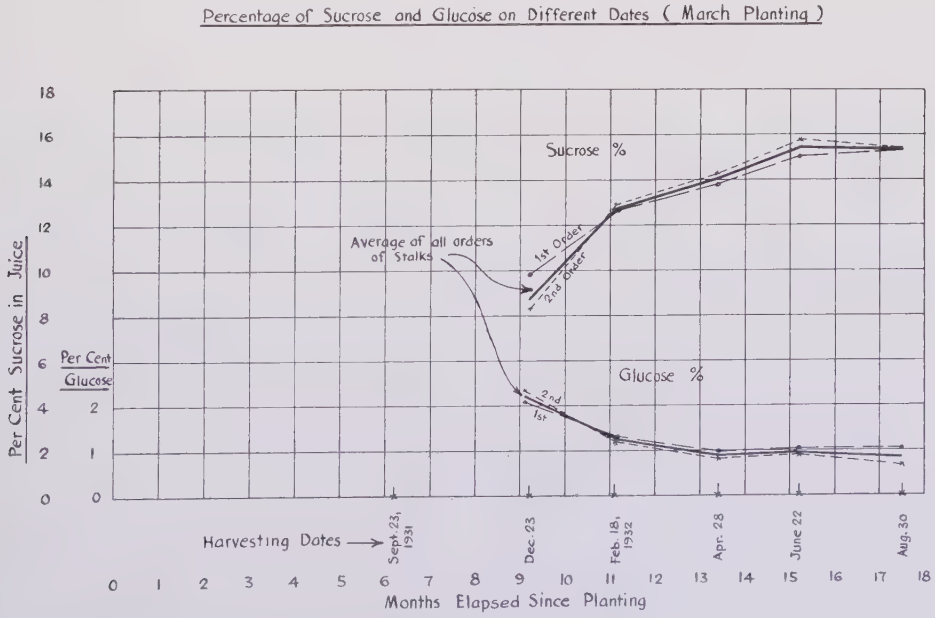


Fig. 6

Also, no attempt was made to withhold irrigation water to ripen cane. The cane received full irrigation right up to the day of harvesting. This fact must be borne in mind in scrutinizing the data.

March Planting

Difference in juice quality in stalks of various orders: Table VII and Fig. 6 show the percentage of sucrose and glucose in juice of the various orders and also the true average for stalks of all orders. It is seen that the average for all stalks is primarily influenced by the average of the stalks of second order. This is to be expected because the second order stalks constitute about two-thirds of the total weight of all stalks. The second order stalks are also seen to be about equally rich in sucrose and in glucose as the first order stalks. This fact is significant when we consider that the first order stalks are in reality about a month to two months older than the second order stalks. Where data are available on stalks of higher order, it is generally found that if we compare juice quality in relation to true age (reckoned from the time of germination) then the stalks of higher order prove superior. In other words, at true comparable ages the later stalks have more sucrose than the early stalks.

TABLE VII

Per Cent Sucrose in Juice in Canes of Various Orders at Different Dates

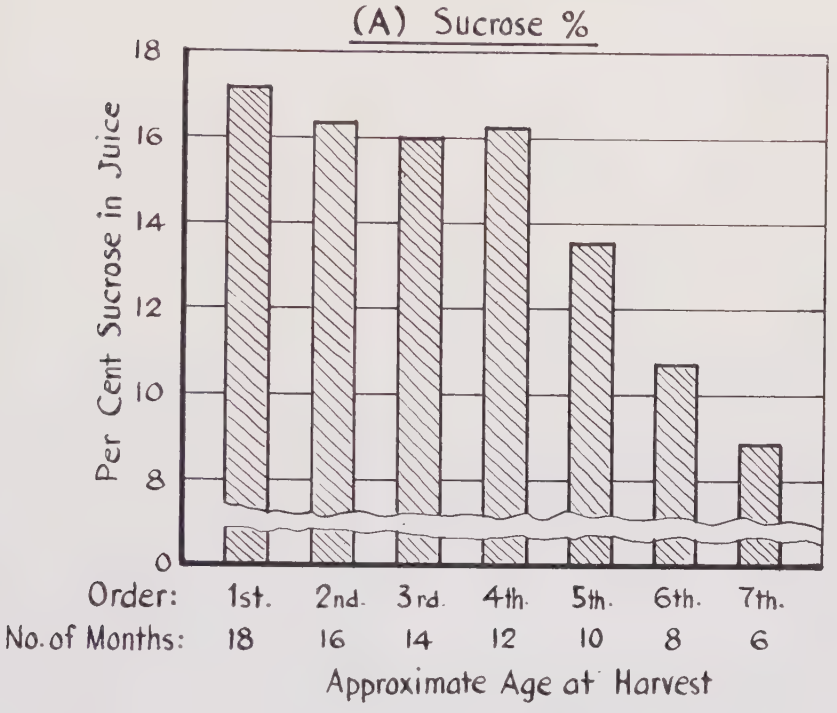
	Date of Harvest				
	12/23/31	2/18/32	4/28/32	6/22/32	8/30/32
First order	9.75	12.65	13.71	15.09	15.27
Second order	8.14	12.83	14.13	15.69	15.37
Average for all* orders	8.60	12.74	13.99	15.37	15.25
Per Cent Glucose in Juice					
First order	2.04	1.33	.97	1.02	1.01
Second order	2.32	1.21	.78	.86	.64
Average for all* orders	2.24	1.25	.84	.93	.76

The harvesting data presented so far consisted of inside lines only, from which we did not get much data on canes of higher order. But we knew from shoot counts that the outside lines had generally more suckers representing many different orders. So we harvested an outside line (Row 1 of Section B) to obtain juice figures from as many different orders of cane as possible. The data, presented in Table VIII and Fig. 7 show that there is a general decrease in the percentage of sucrose and a very regular increase in the percentage of glucose as we go from stalks of first order to stalks of higher order. Under ideal conditions of plentiful light and space and hence little deterioration of old cane, we should expect to find it so. But where the old cane is dying and deteriorating, we shall probably find that the later suckers will, on the average, be richer in quality than the early canes.

* The grand average includes juice from stalks of other and higher orders.

Percent of Sucrose and Glucose in Juice of Stalks of Different Orders.

Section B, Line 1 - Harvested Aug. 29, 1932



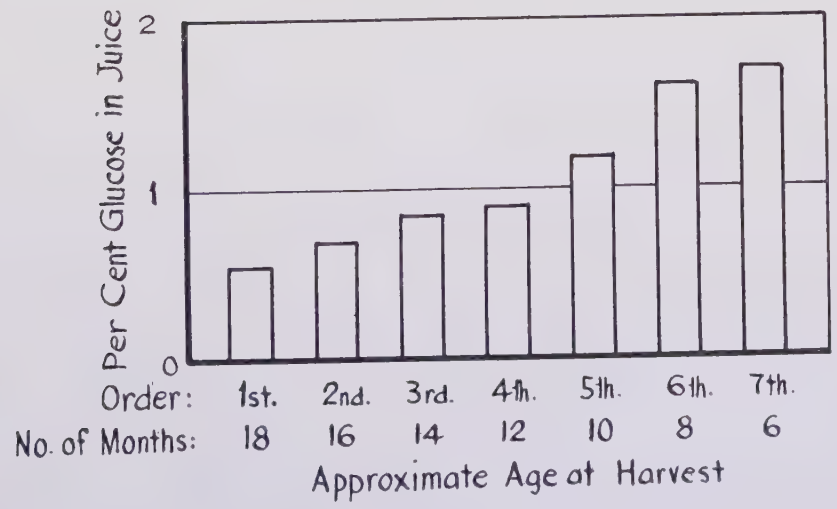

(B) Glucose %
Per Cent Glucose in Juice
2
1
0
Order: 1st. 2nd. 3rd. 4th. 5th. 6th. 7th.
No. of Months: 18 16 14 12 10 8 6
Approximate Age at Harvest

Fig. 7

TABLE VIII

Quality of Juice in Stalks of Different Orders in an Outside Line

Order of Stalk	Per Cent Sucrose	Per Cent Glucose	Approximate True Age at Harvest	Per Cent Sucrose ÷ True Age at Harvest
First order	17.12	0.60	18	0.95
Second order	16.29	0.72	16	1.02
Third order	16.08	0.84	14	1.15
Fourth order	16.16	0.91	12	1.35
Fifth order	13.54	1.19	10	1.35
Sixth order	10.68	1.60	8	1.34
Seventh order	8.92	1.72	6	1.49

Differences in juice quality in the different parts of the same stalk: From a practical standpoint, the differences in the quality of the same stalk at different ages may be of even more significance than the difference between successive orders. How does a cane mature? Is the sucrose or glucose content the same in the different parts of the cane? How do seasonal influences or cultural treatments affect the various parts of the cane? With these thoughts in mind, we harvested another outside line of cane (Row 1, Section B). At harvest we segregated the stalks of various orders and each stalk was divided into the following sections, working from the top downward:

(1) Non-millable top with leaves;
(2) Millable cane.

The millable cane was further divided into four sections:

(a) The green-leaf part;
(b) The top 4 feet of cane remaining after the removal of the green leaf part;
(c) The extreme bottom 4 feet, i.e., 4 feet of cane right above the ground;
(d) The section between b and c, herein called the middle section.

The green-leaf part is defined as that part of cane where the attached leaves are still wholly or partly green. In actual practice the green-leaf part ended at a point where on removing the leafsheath no scar was left on the stalk. It is believed that since to this section only are the green leaves attached, this would also be the zone of most active sucrose accumulation. The results obtained appear to justify such belief.

The cutting of cane according to the above scheme, appears to have merit, especially for the purposes of fundamental study, over the general practice of cutting cane into equal sections working from the bottom upward. Let us consider the case of a sucker which is 8 months old and contains, say, only 4 feet of cane. In the old practice, we would be comparing the bottom of this young cane with the bottom of an old, say, an 18-month cane. One can easily see that the comparison would hardly be valid, for the simple reason that the two sections did not grow at the same time. In the present scheme, this sucker would only have

a top section (for we shall work from top downward) and this will be compared with the top section of an old cane. There is greater probability that both these sections were growing at the same time and, therefore, were equally influenced by environmental factors. Thus it happens that where the length of cane is less than 8 feet we have obtained only top and middle sections—and from our point of view this cane consists of no section comparable to the bottom section of a 12- or 14-foot cane. The data are presented in Table IX and Fig. 8.

In regard to sucrose per cent, we see at once that in all orders of stalk there is materially little difference between the different sections of the dry-leaf part of

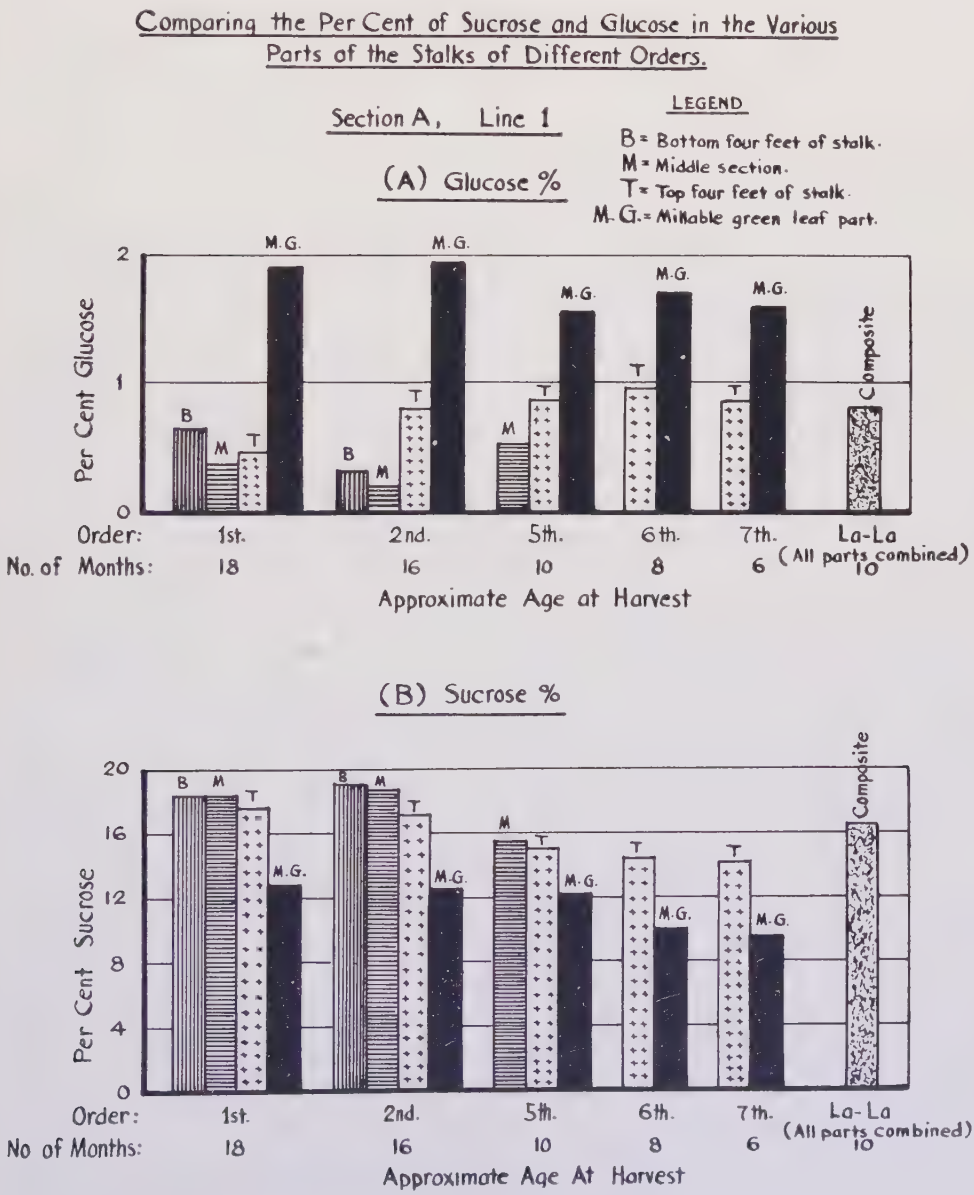

Comparing the Per Cent of Sucrose and Glucose in the Various Parts of the Stalks of Different Orders.
Section A, Line 1
LEGEND
B = Bottom four feet of stalk.
M = Middle section.
T = Top four feet of stalk.
M.G. = Millable green leaf part.
(A) Glucose %
Per Cent Glucose
Order: 1st. 2nd. 5th. 6th. 7th. La-La
No. of Months: 18 16 10 8 6 10
(All parts combined)
Approximate Age at Harvest
(B) Sucrose %
Per Cent Sucrose
Order: 1st. 2nd. 5th. 6th. 7th. La-La
No of Months: 18 16 10 8 6 10
(All parts combined)
Approximate Age At Harvest

Fig. 8

the millable cane (i.e., the part of millable cane without the green-leaf section). But from there to the green-leaf part, there is a sudden decline in sucrose content. In other words, we may say that the green-leaf section is still in the process of gathering sucrose, while the dead-leaf part has reached a certain state of maturity. We do not imply that the level of sucrose in the dead-leaf part will not rise any further. In fact, it does rise to a certain extent, but what we do emphasize is this, that the green-leaf part is the one that is capable of the most advancement in sucrose; this is the part that is growing now and will be comparatively more susceptible to present environment and treatments than any other part.

The relative proportion of the green-leaf part to the dead-leaf section is, therefore, a matter of very great importance from a practical standpoint; for the average juice of a stalk is a composite between these two sections. The superiority of an old cane over a young sucker is undoubtedly due in a large measure to the fact that in young, vigorously growing suckers the green-leaf part may constitute fully one-third of the whole millable stalk. In the old cane it may be, and generally is, about one-eighth or one-tenth of the whole stalk. Even if the sucrose content in the dead-leaf and green-leaf sections of the two canes were identical, we shall find a great difference in the average juice quality of the two canes, much in favor of the old cane. The data obtained are similar to observations made originally in Coimbatore, India, and are also substantiated by other data obtained in this experiment.

Now the question will arise in one's mind as to what actually happens when we withhold water from the maturing cane. We have seen that the dead-leaf section had reached a certain state of maturity long before harvest time and the accumulation of sucrose in that part was mostly influenced by conditions of environment and culture that is now past history. Could it not be that in ripening off we are concentrating our efforts primarily on the green-leaf section? True, the withholding of water may drive off a small percentage of moisture from the cane, but probably the greatest thing it does is to stop new growth, and at the same time add more to the dead-leaf section by reducing the size of the green-leaf section.

These discussions will also raise the question if our pre-harvest sampling of cane may not be made more reliable by obtaining information on the relative proportion of dead-leaf and green-leaf parts of representative stalks. It is quite probable that we may be able to substitute a few physical measurements of the different parts of stalks for actual juice analysis; and therefrom get the desired information on the progress of ripening of a field.

Another interesting fact emerges out of Table IX and Fig. 8, that the lalas (side shoots) on canes of the first and second order have a juice quality more approaching the average of the stalks on which they are growing than the young suckers with which these lalas are comparable in age. This would indicate as though the lalas formed an integral part of the big cane and maintained the same level of sucrose concentration as the old stalks.

Point of maximum sucrose content: In this 18-month-old cane the maximum concentration of sucrose is still in the extreme bottom section. These results are

contrary to the accepted belief that as the cane grows old the point of maximum richness invariably moves towards the top. However, later harvests may give different results.

Glucose in the various parts: As in the case of sucrose, the concentration of glucose also changes suddenly as we move from the dead-leaf to the green-leaf section. This sudden increase in the amount of glucose in the green-leaf section again points to the conclusion that this is the part of cane where active processes are going on. It is interesting to note that the lowest concentration of glucose is not in the extreme bottom section, but in the "middle" section of the first and second order stalks. This may indicate a breaking down of sucrose in the extreme bottom, due to age or to demands made by the rhizome and the roots.

TABLE IX

Per Cent of Sucrose and Glucose in the Different Parts of the Stalks

	Sucrose Per Cent				Glucose Per Cent			
Section	A Green-leaf Part	B Top 4′ of Cane	C Bottom 4′ of Cane	D Middle Section	A Green-leaf Part	B Top 4′ of Cane	C Bottom 4′ of Cane	D Middle Section
First order	12.85	17.52	18.51	18.34	1.882	.435	.661	.339
Second order	12.52	17.23	18.97	18.77	1.955	.797	.327	.197
Fifth order	12.18	15.19	....	15.52	1.540	.874	...	.500
Sixth order	9.98	14.30	....	....	1.698	.991	...	...
Seventh order	9.58	14.22	....	....	1.576	.861	...	...
Lala-combined green-leaf and dead-leaf part				16.38			.791	

September Planting

As stated previously, we have had only two harvests so far from September planted cane. The advancement in richness of juice of various orders appears to be following the same trend as in the March planted cane. In Section E, where part of the cane did not receive full sunlight in the earlier stages, the quality of juice appears to be very inferior to that of the stalks which were more fully exposed. This difference is seen both in the green-leaf and the dead-leaf sections of the two groups of stalks (Table X). Thus in addition to being less in weight per stool, these "partly shaded" stools are also lower in quality. Similar conditions probably exist on some of our plantations which are deprived of sunlight during part of the day.

TABLE X

Per Cent Sucrose in the Juice of Shaded and Unshaded Stools
Harvested September 8, 1932

	First Order		Second Order	Third Order
	Green-leaf Part	Dead-leaf Part		
Shaded stools	8.46	12.59	10.88	11.76
Exposed stools	10.15	13.83	12.84	12.61

Conclusions

In the foregoing pages, data have been produced to show that suckering is more or less a continuous process in a field of cane and that it is affected mainly by exposure to light and plant competition. It has been pointed out that a crop generally consists of cane of different age groups, which are materially different from each other both in quality and total quantity. It has also been shown that the average juice quality of a crop is a composite between the stalks of different ages and that within the same stalk this quality is also a composite between the dead-leaf and the green-leaf parts. It is suggested that only through these conceptions of the elements of a crop can we hope to gain a clearer understanding of the interrelated problems of cane tonnage and quality.

Fig. 9. Showing the March planted cane (big cane) to the right and the September planted cane (small cane) to the left. The right end stools of small cane were shaded in the forenoon by the big cane. These stools were late in stooling out and at harvest the stalks weighed less and had less sucrose than the stools towards the left which received full sunlight.

Fig. 10. All the stalks shown in the picture grew originally from one single eye of cane. This one stool is from an outside row of cane and it contains stalks ranging in age from 4 months to 18 months. This is an extreme case to be sure, but this illustrates that under favorable conditions of light, space, and food, suckering is a continuous process in a field of cane.

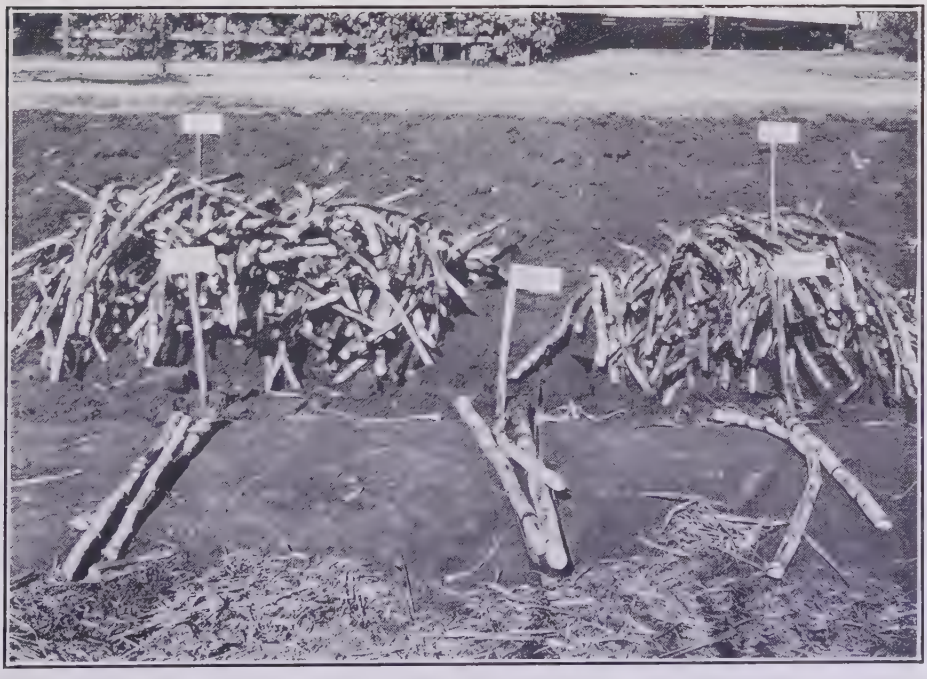


Fig. 11. Showing the quantity of cane of different orders harvested from one inside line of cane in this experiment. At the time of harvest the field was 20 months old.

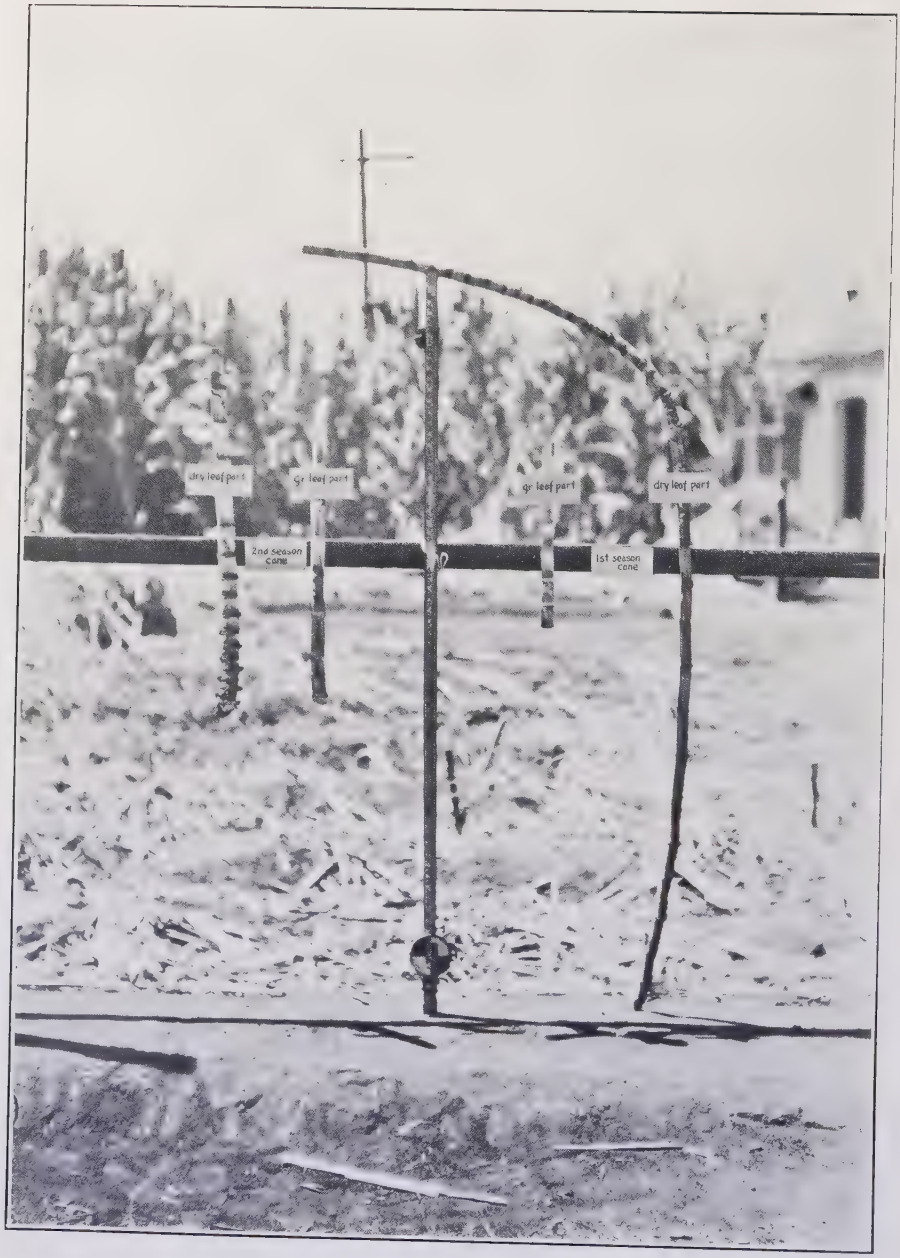


Fig. 12. This illustrates that in a first season cane, the green leaf part (the part containing little sucrose and much impurity) constitutes only a seventh or an eighth of the whole stalk. In the second season sucker, this green part is fully half as much as the whole stalk. The relative proportion of this green part of the stalk to the rest of the stalk has a very important bearing on the average richness of the whole stalk.

Fig. 13. The stick to the left is a sucker of the fifth order. At the time of harvest it was 10 months old. To the right is a lala growing from a first season cane, only part of which is shown. This lala is also 10 months old, but the richness of juice of the lala is very much higher than the fifth order shoot with which it is comparable in age and nearly approaches the richness of the first season cane on which this lala is growing.

Fig. 14. Here are three stalks in different stages of vigor as shown clearly by the manner of growth of the tops—by the spread and number of leaves, etc. The most vigorous one on the extreme left has a large green leaf section, the one on the extreme right a very small green leaf section of millable cane. It is suggested that the maturity of a stalk can well be judged by noting the length of this green leaf part and the proportion it bears to the whole stalk.

Further Observations Upon the Relation Between Cane Elongation and Soil Moisture

By H. A. Wadsworth

Introduction

In a previous paper (6) the writer in cooperation with U. K. Das pointed out that no visible physiological distress was noted in sugar cane when the moisture in the soil supporting the plant reached or dropped somewhat below the permanent wilting percentage. Most other plants that have been studied, except the xerophytes, give evidence of moisture deficiency by some symptoms of flaccid tissue such as drooping or rolling leaves at and below this critical soil moisture constant.

The early studies with cane indicated that an exception must be noted with this plant. Although some physiological disturbances might be expected at the soil-moisture content, known as the wilting percentage, this disturbance was by no means sharply defined. Cane plants in soils considerably below the permanent wilting percentage, showed little sign of flaccid tissue and any leaf rolling, which did occur during the middle of the day, was eliminated during the conventional exposure to the saturated atmosphere which is required by the usual procedure (1).

However, it was noticed that the rate of growth, as measured by the elongation of the primary shoot, was significantly reduced when the soil-moisture content was near the permanent wilting percentage for the particular soil, as determined with sunflowers in the conventional manner.

Further and more elaborate investigations of the responses of sugar cane to soil moisture were undertaken by H. R. Shaw and the writer at Waipio. Here under the conditions existing in tanks in the open the assumption that cane elongation proceeded at a uniform rate until the soil-moisture was reduced to the wilting percentage and then ceased, to be resumed only upon the addition of water to the soil, seemed justified. Details of the observations leading to this conclusion were presented at the annual meeting of the Hawaiian Sugar Planters' Association in 1930.

Continued interest by Mr. Shaw and others has demonstrated that the simple conception that the normal rate of growth is suddenly reduced to no growth at all when the soil moisture falls to the wilting percentage need not be true. As a result of work in the H. S. P. A. greenhouses, Shaw and Matsusaka (5) note a soil-moisture zone of 3 or 4 per cent lying near the permanent wilting percentage in which cane growth may be seriously handicapped. The sharp discontinuity between normal growth and no growth is not found by these workers, this discontinuity being replaced by a transitional curve of some considerable length. Observations of elongation were apparently made at daily intervals. Bond, working with plants in the field at Ewa, reports a similar decrease in the rate of growth immediately preceding complete cessation.

The interest evidenced at the annual meetings of the H. S. P. A. in 1930, when these results were presented, has prompted a continued study at the University of Hawaii. Many refinements in the methods used in measuring elongation were attempted. The possibility of using a slow speed moving picture camera to record growth was explored but abandoned.

The Optical Lever

Although the optical lever has apparently never been used in measuring plant responses, the device in a modified form proved suitable in measuring the elongation of the primary shoot of potted plants in the greenhouse. Essentially, the lever consists of a small circular mirror mounted vertically upon a brass block from the bottom side of which two sharp steel pins extend. A section of light brass rod, one end of which is bifurcated, extends through the block and is normal to the mirror. In operation the lever is mounted on a steel bar carrying depressions for the steel points mentioned above, while an ordinary household pin secures the point at which growth is to be measured between the two sections of the bifurcated end. When properly made, the lever balances upon its supports and the point in the plant perforated by the pin is neither under tension nor compression. A close up of two levers applied to a single cane plant is shown in Fig. 1.

It is evident that the vertical displacement of the pin through the plant will result in a deflection of the mirror and that the magnitude of this deflection may be observed by a laboratory telescope and scale. In the present installations a paper scale, divided into millimeters, is mounted on the concave arc of a circle with a radius of 100 cms. The arc with its scale is mounted in the plane normal to the mirror. A laboratory telescope, so mounted that its center line is at the same height as the center of the mirror, carries the image of the scale in its field. The cross hair in the telescope provides a basis for measurement. The details of the parts and their assembly are shown in Figs. 1 and 2. In the upper lever illustrated in Fig. 1, the distance from the mirror to the pin is 10 cms., while that from the mirror to the scale is 100 cms. This ratio of 1:10 must be increased twofold because of an optical factor which may be readily demonstrated. The apparent magnification of growth by the upper lever in Fig. 1 is 20 times. The geometry of the optical system and its limitation has already been described (7).

It is also evident that observations of the vertical displacement of an arbitrary point on the leaf bundle gives no direct evidence of the vertical displacement of the last visible ligule since several feet of leaf may be produced during the formation of a few inches of cane. Consequently, two levers were used on each plant. One of these, with an effective ratio of 1:20, has already been described. A second, the lower in Figs. 1 and 2 and built for a ratio of 1:40, was attached to the ligule in such a way that the vertical displacement of the ligule might be observed through a second telescope. Observations on rates of growth are classified as leaf displacement and ligule displacement. Due recognition must be made of the differences in the optical ratios involved.

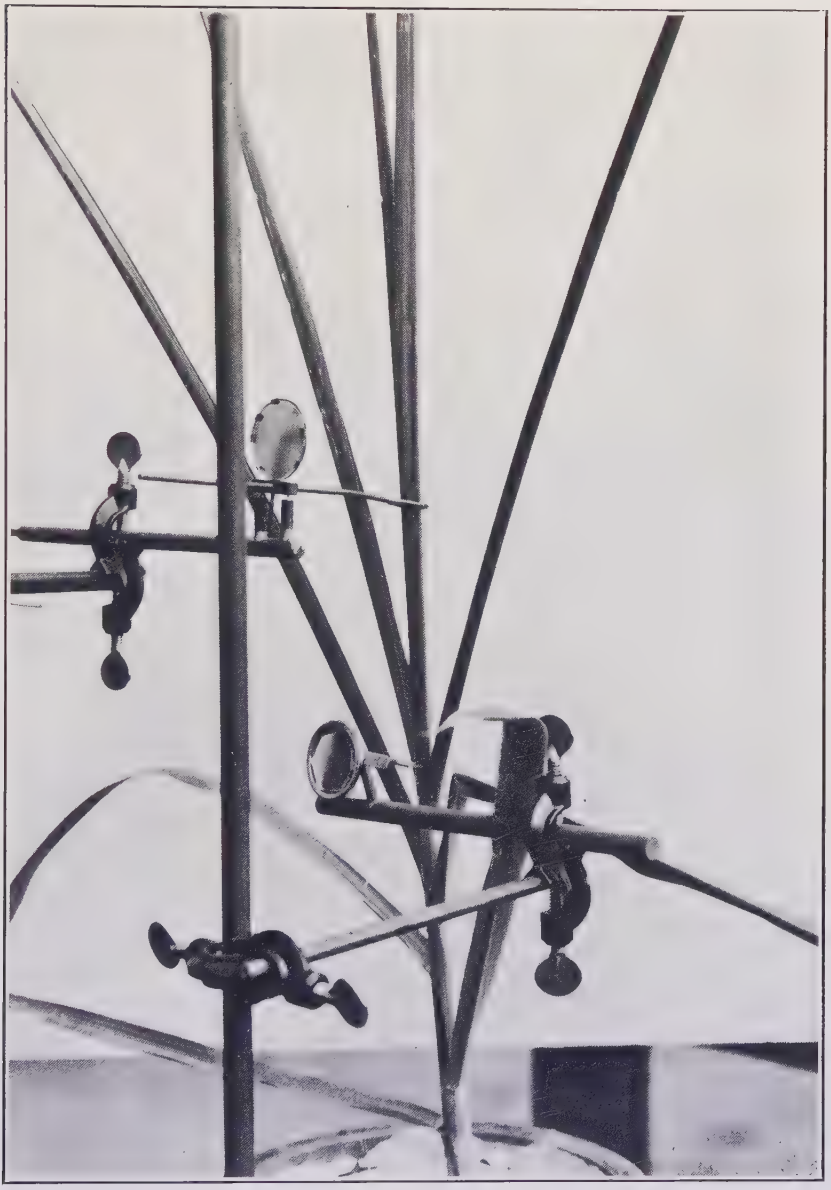


Fig. 1. The optical lever as used in studies of cane elongation. The upper lever provides a 20-fold magnification of rate of growth. The lower lever on the ligule gives a magnification of 40. (University of Hawaii photograph.)

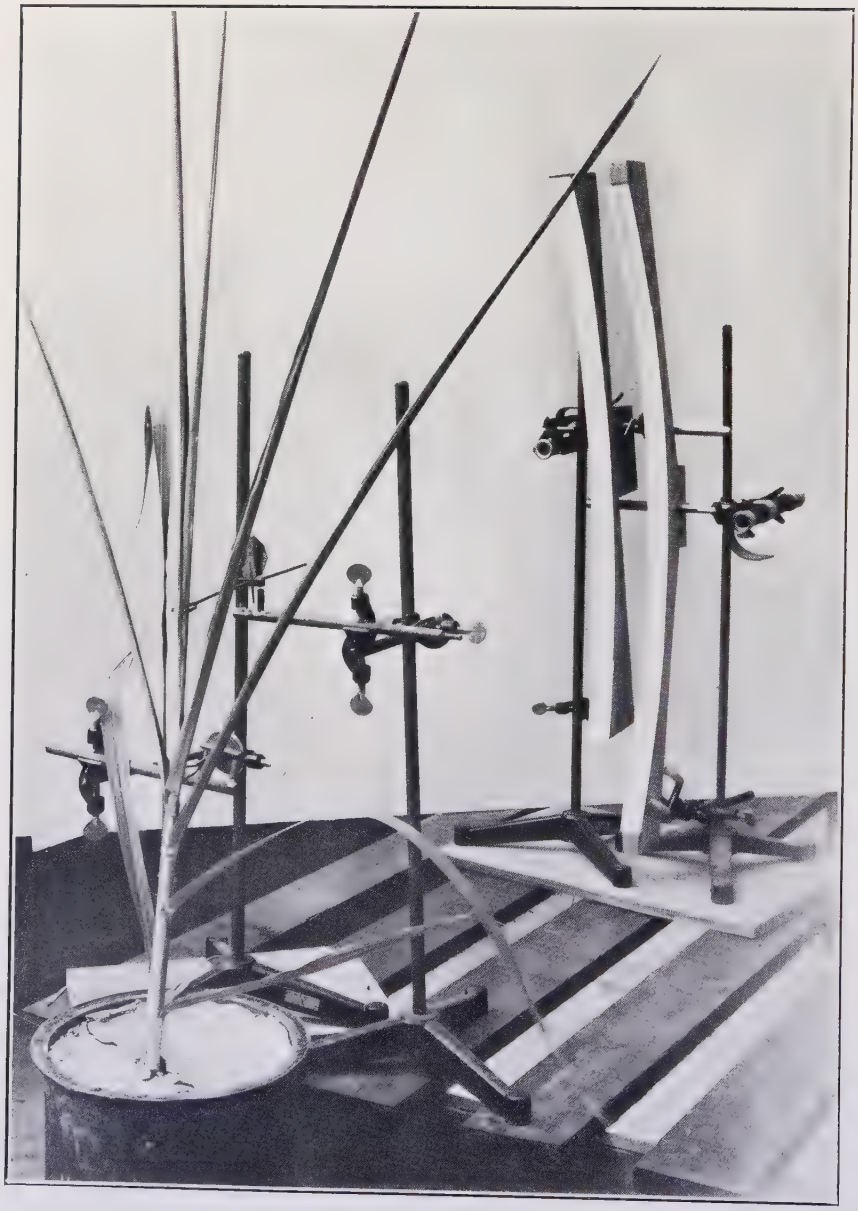


Fig. 2. General view of lever assembly, showing positions of telescopes and scales. (University of Hawaii photograph.)

The Observations

Soil for the specimen plant was secured from the Waipio substation of the H. S. P. A. and exhibited a moisture equivalent of 29.7 ± .16. This material was carefully screened and placed in a specially prepared copper container with a diameter of 10 inches and an effective soil depth of 15 inches. A healthy plant of cane (variety H 109) was transplanted from a two-months-old planting to the soil mass and the system irrigated to maximum field capacity. After three weeks, which were allowed for the reestablishment of the root system, the soil was irrigated once more, the soil-surface tightly covered with lead foil to reduce surface evaporation, and observation begun. In general, observations were made at least five times a day during the first month of observation and twice daily, namely, at 7:00 a. m. and 4:00 p. m., for the rest of the period. In each case the position of the reflected beam was noted on the scale and the deflection of the beam during the period computed as a difference. The continuous summation of these vertical displacements naturally gives the growth history with great precision, in view of the effective magnification. Frequent adjustments of the mirror were necessary since the reflected beam, during normal growth, would swing over the entire range of the scale in something less than 12 hours. In general, weighings were made at the first observation in the morning, normally at 7:30 a. m., although additional weighings at 4:00 p. m. were added during the second half of the period of observation.

Results

The complete data for the entire series of observations, extending continuously from February 21 to April 9, cannot be presented within practicable limits. Nor are they necessary. A study of this material, however, indicates that the total elongation for a 24-hour period is essentially constant for a considerable time after each irrigation of the soil mass as Shaw and Matsusaka (5) have already pointed out. In the present case the average rate of elongation during the first half of the first series of observation was 89.2 ± 6.0 scale centimeters per day. The corresponding result during the second half of the same series was 89.4 ± 5.6 scale centimeters per day. At the end of this period of essentially uniform elongation and at a moisture content somewhat above the permanent wilting percentage, a reduction in growth accomplished during a 24-hour period sets in and a gradual curtailment of growth brings the elongation to a stop within a few days. At the end of this period no growth is observable nor can growth be resumed without an application of water.

This aspect of the study may be illustrated by Fig. 3, which gives the results of detailed observations upon leaf extension between 7:00 a. m. March 21 and 4:00 p. m. March 28. During this period the rate of growth declined from normal growth to no growth, the transition curve extending from March 23 to March 26. The curve in Fig. 3 is perfectly typical of all cases involving a similar soil moisture range.

It will be noted, in Fig. 3, that the smooth curves heretofore used to express the rate of growth can no longer be used if more than one observation a day is

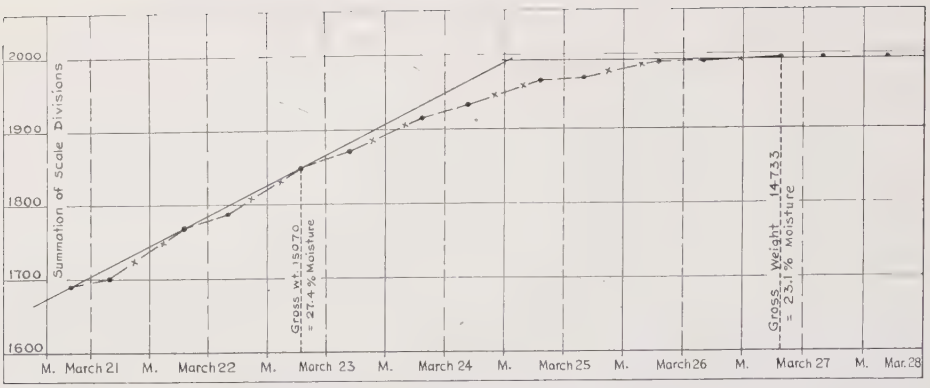


Fig. 3. Length growth history of sugar cane in soil near the permanent wilting percentage. The cane is under greenhouse conditions.

plotted. The first three morning observations are in themselves collinear as are the corresponding observations at four in the afternoon. But no single straight line can contain all six points. And the same relation would be noted if the curve were extended to the left, that is, into dates prior to March 21. In the figure the rate of growth during the heat of the day is indicated by a broken line, while the rate during the night is indicated by a broken line with crosses. The differences in slope are evident and it becomes apparent that under greenhouse conditions the rate of growth, even at high moisture contents, is greater during the night than during the day. As the moisture content falls, both rates are reduced and on March 26 there was no growth in either period. The flat arm of the growth curve previously noted for low moisture contents naturally results.

The observations plotted in Fig. 3 relate to the first growth cessation in a series of three. Reduced daily elongation was first noted at a gross weight of 15,070 grams, which, in view of the tare weights involved, indicates an average moisture content of 27.4 per cent. Elongation essentially ceased at a gross weight of 14,733 or 23.1 per cent moisture.

These data together with corresponding observations for the other two periods of retardation, are given in Table I.

TABLE I

Critical Weights, Dates and Soil-Moisture Percentages for Three Successive Periods of Growth Retardation With Sugar Cane

	Retardation Begun			Retardation Ended		
	Date	Gross Weight in gms.	Soil Moisture Per Cent	Date	Gross Weight in gms.	Soil Moisture Per Cent
1st Period	March 23	15,070	27.4	March 27	14,733	23.1
2nd Period	April 3	15,050	27.3	April 6	14,720	23.0
3rd Period	April 13	15,140	28.2	April 15	14,725	23.1

The interesting but not unexpected finding that growth was more rapid during the night than during the day prompted a still more detailed study of this aspect.

The soil was irrigated to maximum field capacity on April 6 and had regained normal growth on the next day. A series of detailed observations was begun on April 8. Due to the cooperation of University students in irrigation courses, it was possible to secure observations at 15-minute intervals for the 26-hour interval beginning at 2:00 p. m. on April 8, and ending at 4:00 p. m. on the following day.

Two optical levers were in use. One on the leaf had the usual 1:20 ratio, while one attached to the last visible dewlap or ligule had a 1:40 ratio. In addition to observations upon growth, the system was weighed upon the even hours as a measure of transpiration losses. Temperature observations were made at 15-minute intervals. A centigrade thermometer was used, readings being made to the nearest tenth of a degree.

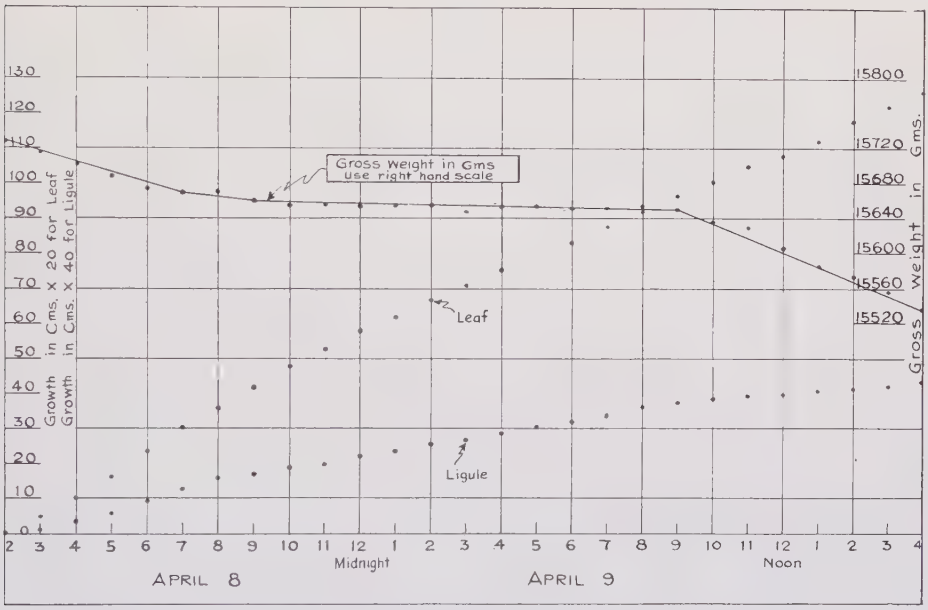


Fig. 4. Growth history of small cane plant for a 26-hour period immediately after an irrigation. Based on observations at 15-minute intervals.

Partial results are presented graphically in Fig. 4. The series of points marked "leaf" gives the growth history of a point on the central spindle. The scale on the left starts from an arbitrary datum. Actual elongation may be secured by dividing the scale increase for any period by 20. Similarly, the lower series of points represents the elongation of the stalk as measured by the last visible ligule. In this case the factor is 40. In each case the detailed observations for the quarter hours are omitted in Fig. 4 for clarity. When plotted they fall close to their interpolated positions.

Little can be judged of relative rates of growth from 4:00 p. m. to 7:00 a. m. and 7:00 a. m. and 4:00 p. m. from Fig. 4 in the case of the leaf bundle. However, statistical interpretation indicates that the elongation is more rapid during the

night than during the day even at the high moisture content present only 48 hours after irrigation. The results are given in Table II.

The difference in rates is more marked in the case of the vertical displacement of the ligule. The average rates for the two periods are given in the following table:

TABLE II

Average Rates of Elongation in Scale Divisions per Quarter Hour for Critical Periods of the Day (See Fig. 4)

	NIGHT			DAY			
	From	To	Elongation*	From	To	Elongation*	Difference
Leaf	4 P.M.	7 A.M.	1.293 ± .028	7 A.M.	4 P.M.	1.092 ± .026	0.201 ± .038
Ligule	4 P.M.	7 A.M.	0.508 ± .020	4 A.M.	7 P.M.	0.244 ± .020	0.261 ± .025

Since a difference is assumed to be statistically significant, if it is five times its probable error, it may be assumed that the growth of both critical points under the conditions of the experiment was more rapid during the night than during the day, the difference being greater in the case of the ligule.

It will be noted, too, from Fig. 4 that losses of moisture by transpiration become almost negligible during the hours of complete darkness. And it is during this period that growth is most rapid. It may be remembered that Curtis (2) once said that transpiration was a necessary evil that evolution would at some time correct.

The thermometer readings mentioned above suggest other interesting relations. As has been noted the growth of both leaf and ligule was more rapid during the night with its low temperatures than during the day. If the period of night be defined as between 4:00 p. m. and 7:00 a. m., a correlation coefficient of +0.671 is secured when the average temperature for a 15-minute interval is compared with growth accomplished during the interval. This coefficient may be interpreted as being significant and the positive sign indicates that higher temperature during the night is associated with more rapid growth. This relation changes at the beginning of the day period, the corresponding correlation coefficient being —0.103. Although such a coefficient is probably not significant, we have some evidence that the relation between temperature and growth noted for the night period is significantly changed. Moreover, the negative sign, if significant, indicates that low temperatures are associated with rapid growth during the day.

Another relation is indicated by a study of the average temperature during the hourly periods elapsing between weighings and the observed losses by transpiration during corresponding periods. The average temperature during the period 4:00 p. m. to 7:00 a. m. was 23.2° C. Between 7:00 a. m. and 4:00 p. m., the average temperature was 26.3° C. During the night period the average transpiration was 6 gms. per hour, while during the day the average transpiration reached a value of 15 gms. per hour. An increase of 150 per cent in transpira-

* Elongation given in scale centimeters per hour. To secure actual growth divide elongation by 20 for leaf and by 40 for ligule.

tion with a temperature increase of 3.1° C. seems out of line with the common understanding of factors influencing evaporation even if the differences in relative humidities during the two periods are considered. A logical conclusion is that sunlight has other influences upon the rate of transpiration than temperature alone. The opening of the stoma during periods of light is well recognized but perhaps not fully understood by plant physiologists (3).

The determination of the permanent wilting percentage of the soil in question by means of the usual procedure with sunflowers gave a value of 23.2 ± 0.2 for this constant.

Discussion

As has been pointed out the arbitrary definition for the permanent wilting percentage is the soil moisture content at the time the leaves of a plant growing upon it first suffer a permanent reduction of their moisture content as a result of deficiency of soil moisture supply. The common criterion as to whether or not the permanent wilting percentage is reached is the exposure of the plant with its flaccid tissue to a saturated atmosphere for twelve hours. Evidently the question of rates is implied, if not expressed. If soil moisture can move into a plant as rapidly as moisture is being lost from its leaf structures by transpiration, no flaccid tissue will result. And if sufficient moisture can move into a plant in the dark in twelve hours to restore complete turgidity, the wilting percentage would not yet be reached by the definition.

Evidently the same conception of rates is involved in the present study of cane growth. It is commonly believed that cell division cannot take place except with perfectly turgid cells, nor can cell enlargement proceed in the case of flaccid tissue. The two factors which might be responsible for the growth responses noted seem dependent upon complete turgor.

Evidently the rate at which moisture may be made available to the plant depends not only upon the rate at which it may be removed from the soil but upon the capacity of the plant structure to convey that moisture to the point of need. Moreover, the transpirational demand seems to vary greatly as indeed one might suppose. A hot, bright day of low humidity might well establish such a demand for water that flaccid tissue might result regardless of the soil-moisture content.

A normal day in the greenhouse seems to approach this condition. Factors making for transpiration are so intense that complete turgidity cannot be maintained, consequently, growth is curtailed. The darkness and coolness of the night seems to re-establish the balance between the rate of income and outgo and complete turgor permits maximum growth. It is very probable that similar observations in a well ventilated greenhouse or in the field, if sufficient precision of measurement might be secured, would fail to disclose the difference between day growth and night growth here reported. If the rate of transpiration is not more than the possible rate of income, normal turgor should prevail and growth should be unaffected.

Another factor is introduced by soil-moisture contents near and below the wilting percentage. Here the residual soil moisture is so firmly held that move-

ment into the root may be at an extremely slow rate. The amounts of water moving into the plant during periods of reduced transpiration become successively smaller as the soil moisture is reduced and the period of most active growth during the day becomes shorter.

It would seem plausible at least to assume that the transitional curve between normal growth and no growth would be less marked with respect to time as well as soil moisture percentages under conditions of constant transpirational demands than under greenhouse conditions. For in the former case no storage of water in the plant would be possible during hours of lessened demand. In the greenhouse, however, or in the field under conditions of hot, dry days and cool nights, one might expect a short period of maximum growth each day at relatively low moisture contents due to the turgid tissue resulting from the reduced transpiration of the night. All observations under greenhouse conditions note a significant retardation curve. At Waipio, under field conditions, the transitional retardation was hardly significant, while at Ewa it was easily noted with field measurements.

This hypothesis seems to find further support in the residual soil-moisture contents at the time of complete growth cessation. As has been noted, growth ceased in all three cases at a moisture content close to 23.0 per cent. From the agreement above, it would follow that a flaccid cane plant in the soil in question was unable to regain sufficient turgor during the hours of the night to resume elongation. If it be assumed that complete turgidity is necessary for growth of this type, the soil-moisture at this point is essentially the permanent wilting percentage. It would follow that the percentage of soil-moisture present when the reduced rate of growth gives place to no growth at all should be numerically equal to the permanent wilting percentage as determined by other plants. The close agreement between 23.2 per cent as the residual soil moisture at permanent wilting of sunflowers and 23.1 per cent at the time of growth cessation seems to support this assumption. The same conclusion has been reached by Shaw and Matsusaka (5) as a result of an exhaustive series of observations upon many soils.

An optical lever for field use is now being constructed.

Summary

(1) An optical device which permits precise measurement of cane elongation at varying soil-moisture percentages is described.

(2) No significant difference is noted between the rate of vertical displacement of a point on the leaf bundle on a cane plant during high soil-moisture percentages and low soil-moisture percentages provided the soil moisture is always at least 3 per cent above the permanent wilting percentage.

(3) A long and significant transition curve between normal growth and no growth is noted under greenhouse conditions.

(4) Growth during the night is at a more rapid rate than growth during the day under greenhouse conditions.

(5) Transpiration losses during the night are small.

(6) It seems reasonable to assume that the period of retarded growth immediately preceding total growth cessation would be reduced in conditions offering less extreme difference in transpirational demands than encountered in the greenhouse. If such be the case, the permanent wilting percentage becomes a close approximation of the soil moisture content at which cane ceases its economic growth.

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Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
JUNE 17, 1932, TO SEPTEMBER 15, 1932

Date	Per Pound	Per Ton	Remarks
June 17, 1932	2.89¢	$57.80	Philippines, 2.88; Porto Ricos, 2.90.
" 20	2.90	58.00	Cubas, Porto Ricos, Philippines.
" 21	2.835	56.70	Philippines, 2.85; Cubas, 2.82.
" 22	2.80	56.00	Porto Ricos.
" 23	2.90	58.00	Philippines.
" 28	2.8633	57.27	Cubas, 2.88, 2.85; Porto Ricos, 2.86.
" 29	2.80	56.00	Porto Ricos, Philippines.
July 5	2.97	59.40	Philippines.
" 6	2.95	59.00	Porto Ricos, St. Croix.
" 7	2.99	59.80	Porto Ricos, 2.95, 3.00; Cubas, 3.00, 3.02; Philippines, 3.00.
" 8	3.05	61.00	Cubas, Porto Ricos, Philippines.
" 14	3.1167	62.33	Cubas, 3.10, 3.12; Porto Ricos, 3.10, 3.13.
" 18	3.10	62.00	Philippines.
" 27	3.07	61.40	Cubas.
Aug. 2	3.08	61.60	Porto Ricos.
" 3	3.085	61.70	Philippines; Cubas, 3.09, 3.08.
" 4	3.08	61.60	Philippines.
" 8	3.10	62.00	Cubas, Philippines, Porto Ricos.
" 9	3.1233	62.47	Porto Ricos, 3.10, 3.15; Cubas, 3.12, 3.15.
" 10	3.15	63.00	Cubas, Porto Ricos, Philippines.
" 11	3.14	62.80	St. Croix.
" 12	3.15	63.00	Cubas.
" 16	3.18	63.60	Cubas, Philippines.
" 19	3.17	63.40	Cubas.
" 26	3.18	63.60	Cubas, Porto Ricos.
Sept. 7	3.16	63.20	Cubas.
" 8	3.15	63.00	Cubas, Philippines.
" 12	3.10	62.00	Cubas.
" 15	3.08	61.60	Cubas.